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THE JANUARY SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

JANUARY 1926

GEOLOGY FROM THE ISOSTATIC VIEWPOINT

By Dr. WILLIAM BOWIE

CHIEF, DIVISION OF GEODESY, U. S. COAST AND GEODETIC SURVEY

THE mysterious earth has puzzled untold multitudes for tens of thousands of years. Each generation has struggled for an explanation of the history of the earth as written in stone, and this history has been only partially translated or deciphered even to the present time, when so much is known of such things as radio, flying machines and the constitution of the atom.

To-day the atom which can not be seen, even with the most powerful microscope, is more completely known than the earth. How was knowledge of the atom gained? By indirect methods and scientific deductions. What is known about the interior of the earth and much of its surface material is gained in the same way.

The earth is now receiving more attention from scientists than ever before. They want to know how deposits of oil, coal and ores were formed and how they may be discovered; the causes of earthquakes which occur daily, some of them most disastrous to man and his works; the causes of the great changes in the elevation of the earth's surface; and many other things which are either interesting or important.

In each year more than five thousand earthquakes register their tremors on the many seismographs in operation throughout the world. Some quakes are felt by human beings, but the vast majority are known only from the record made on the seismograph. What is the relation of the small quake to the large one? Are there areas free from even the feeblest quake? Shall we ever be able to predict the time and place of destructive ones? All these questions are being studied, and while they may never be definitely solved, yet much light will be thrown on them by the accumulation of accurate data as time goes on.

In addition to our knowledge of the surface features of the earth, consisting of mountains and plateaus, valleys and coasts, oceans and lakes, we know that the earth is as rigid as steel, but that in spite of this, under gravitational forces it yields like putty; mountains and continents float; there are no "everlasting hills"; the nucleus of the earth is not contracting and leaving the crust "up in the air," to collapse later on and buckle into mountains; the earth does not have a boiling and bubbling center, with volcanoes as smokestacks; and earthquakes are not caused by world-wide processes, concentrating their forces for any particular quake, such as the destructive ones in Japan and at San Francisco and the one on February 28th of this year, which created so much in-

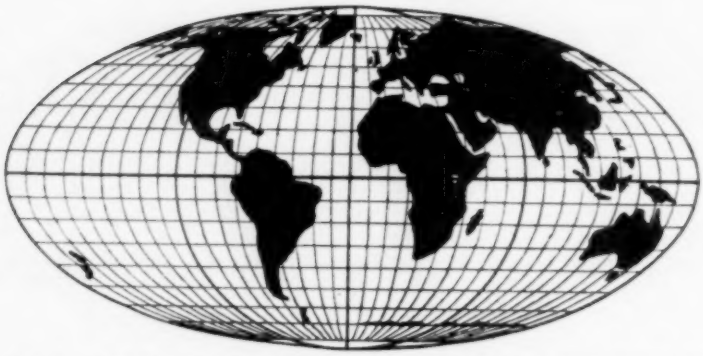

FIG. 1. THE EARTH'S SURFACE IS ABOUT 200,000,000 SQUARE MILES OF WHICH 57,000,000 ARE LAND. THE LAND AREAS ARE USED FOR DETERMINING THE EARTH'S SHAPE AND SIZE, AND IN DECIPHERING THE GEOLOGICAL HISTORY OF THE LAST FIFTEEN THOUSAND MILLION YEARS.

terest and some consternation in the eastern part of the United States.

Earthquakes are due to local forces, originating from change in density of the material of the earth's crust under the region or in the disturbance of the outer portion of the earth by the processes of erosion and sedimentation.

How do we know that these things are true or false? By the processes of the most exact measurement followed by analysis and deduction. A greater quantity of exact measurements with which to study the earth's material has been made during the past century than during the previous thousands of years that man has been on the earth.

The data consist of the determination by observations on the stars of the latitudes and longitudes of thousands of places on the earth and measurements by triangulation of distances between the astronomic stations; the value of the earth's pull or gravity at several thousand places; observations of the time of transmission of earthquake tremors through the earth's materials; the determination of the variation of the relation between the axis of figure and the axis of rotation of the earth; and the observations of the tides of the oceans and of the surface of the land caused by the irregular pull of the moon and sun as the earth rotates.

These data, on their face, do not seem to give much promise as a means of discovering anything of the condition of the earth's material or the processes which have modified its surface, but much has been learned from them.

From the measurements of distances by triangulation and the astronomical observations on the stars, for latitude, longitude and azimuth, the shape and size of the earth have been determined with sufficient accuracy for all practical purposes and most scientific ones. The geodesists are still endeavoring to arrive at a closer value to the true dimensions as geodetic and astronomic data accumulate.

It was with the observations and measurements used to determine the figure of the earth that one of the great discoveries of science was made. This is that the earth's crust is resting on material which acts as if it were plastic. The crust floats on this material as the great ice field of the Arctic floats on the waters of that ocean.

Suppose that, in a basin of mercury, there are placed in an upright position several blocks of different metals, each metal lighter in density than the mercury, and each block with the same weight and the same cross-section. They

would all sink to the same depth. The lower surfaces would form a plane and the upper surfaces would be irregular; the lighter the metal the higher the block would stand above the surface of the mercury.

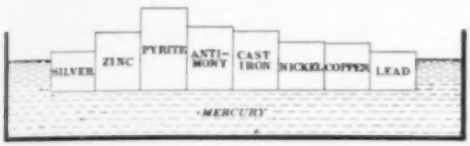

FIG. 2. BLOCKS OF LIGHT METALS OF EQUAL MASS AND THE SAME CROSS-SECTION PLACED UPRIGHT IN A BASIN OF MERCURY WOULD SINK TO THE SAME DEPTH. THIS IS A SIMPLE ILLUSTRATION OF HYDROSTATIC EQUILIBRIUM. THE THEORY OF ISOSTASY IS BASED ON THE PRINCIPLE ILLUSTRATED ABOVE.

By imagination, let the earth's crust be cut into blocks by vertical planes, making squares of say 100 miles on a side. Suppose there were no friction between them. Then they would remain in place without appreciable movement, for each one weighs the same as each of the others. The earth's crust is in equilibrium and floats, just as the blocks of metal float in the mercury.

This theory regarding the earth's crust was first propounded by Pratt, a noted British geodesist and mathematician, nearly seventy years ago, and the idea was hinted at also by Airy.[1] Pratt was led to this theory by the study of the geodetic observations and measurements in India with which he was attempting to determine the dimensions of the earth. The theory was not taken very seriously until Dutton[2] in 1889 delivered his famous lecture in Washington, D. C., at a meeting of the Philosophical Society in which he gave the theory the name *Isostasy*. This term is derived from two Greek words, meaning "equal standing" or "equal pressure."

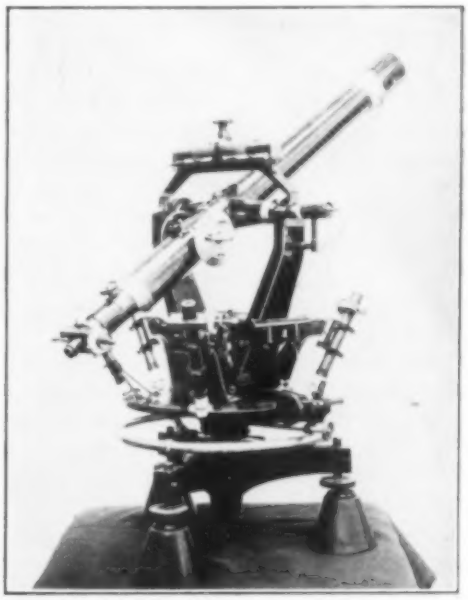

FIG. 3. THE THEODOLITE IS USED BY GEODESISTS IN MAKING MOST ACCURATE OBSERVATIONS FROM WHICH THE SHAPE AND SIZE OF THE EARTH ARE COMPUTED. HELIOGRAPHS AND SIGNAL LAMPS, STATIONED ON MOUNTAIN PEAKS, HAVE BEEN OBSERVED WITH THIS INSTRUMENT FROM DISTANCES GREATER THAN 150 MILES.

Following Dutton, many geologists wrote about the theory of isostasy, some upholding and others condemning it. The first serious attempt to test the theory by actual measurements was made by Putnam[4] in the nineties when he was a member of the U. S. Coast and Geodetic Survey. He used for this purpose a few gravity stations, widely scattered over this country. Putnam's conclusion was that the United States, as a whole, is in isostatic equilibrium, but that mountain ranges are probably supported by the crust as extra loads. Gilbert,[4] discussing Putnam's results,

[1] J. H. Pratt, Philosophical Transactions of the Royal Society of London, Vol. 145, page 52. G. B. Airy, Philosophical Transactions of the Royal Society of London, Vol. 145, page 101. J. H. Pratt, Philosophical Transactions of the Royal Society of London, Vol. 148, page 745.

[2] C. E. Dutton, "On some of the greater problems of physical geography," *Bulletin*, Washington Philosophical Society, Vol. 11, pp. 51–64.

[4] G. R. Putnam, "Relative determinations of gravity with half-second pendulums and other gravity investigations, with notes on geological formations by G. K. Gilbert," U. S. C. & G. Survey Report for 1894, App. 1.

decided also that the earth's crust holds up mountain systems.

Following Putnam, Hayford made investigations resulting in two reports[5] on the figure of the earth and isostasy. He proved the theory to be substantially true for the United States. He used hundreds of astronomic stations and thousands of miles of arcs of triangulation in the United States, largely resulting from the work of the Coast and Geodetic Survey.

Hayford found that not only the United States as a whole is in isostatic equilibrium, but that even portions of the earth's crust of moderate size are in equilibrium. He found that the crust of the earth within which abnormal densities occur extends to a distance of about seventy miles below sea level.

[5] J. F. Hayford, "Figure of the earth and isostasy from measurements in the United States," and "Supplementary investigations in 1909 of the figure of the earth and isostasy." These are publications of the U. S. Coast and Geodetic Survey.

When Hayford left the Coast and Geodetic Survey to take up the duties of director of the college of engineering of Northwestern University in 1909, the isostatic investigations of the Coast and Geodetic Survey were continued by the writer with the assistance of Messrs. C. H. Swick and W. D. Lambert and Miss Sarah Beall, mathematicians in the Division of Geodesy of the Survey.

In this later work there were used the values of gravity at more than three hundred stations in the United States and over forty stations in Canada. The writer's results confirmed Hayford's and proved beyond doubt the theory of isostasy.

Briefly stated, the results of all the isostatic investigations are: The earth's crust is in a state of almost perfect equilibrium; the crust extends approximately sixty miles below sea level; the weight of a block of the crust of unit cross-section, say one hundred miles square, is the same within a very small

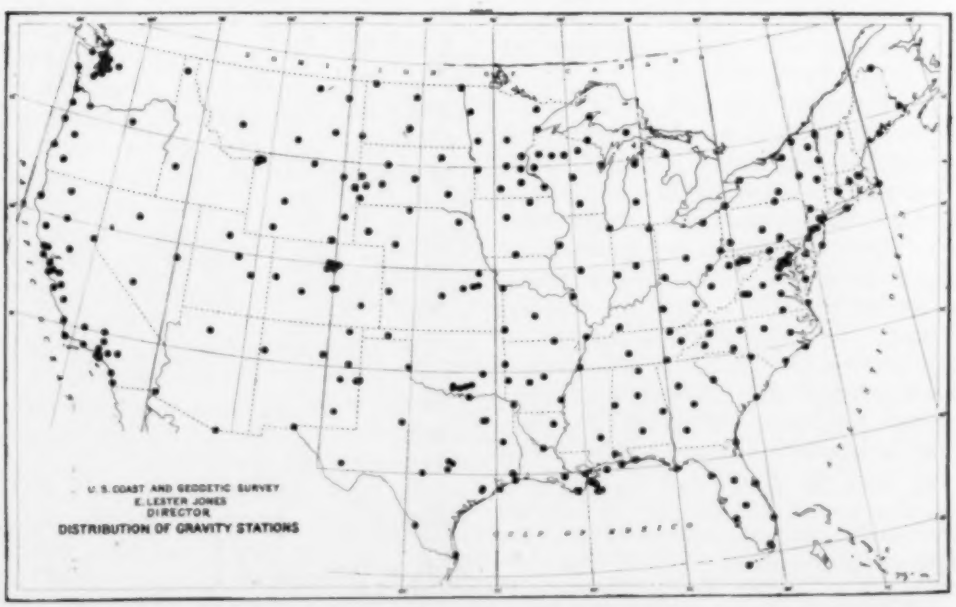

FIG. 4. HUNDREDS OF GRAVITY STATIONS IN THE UNITED STATES AND IN OTHER COUNTRIES HAVE BEEN USED TO PROVE THAT THE EARTH'S CRUST IS FLOATING.

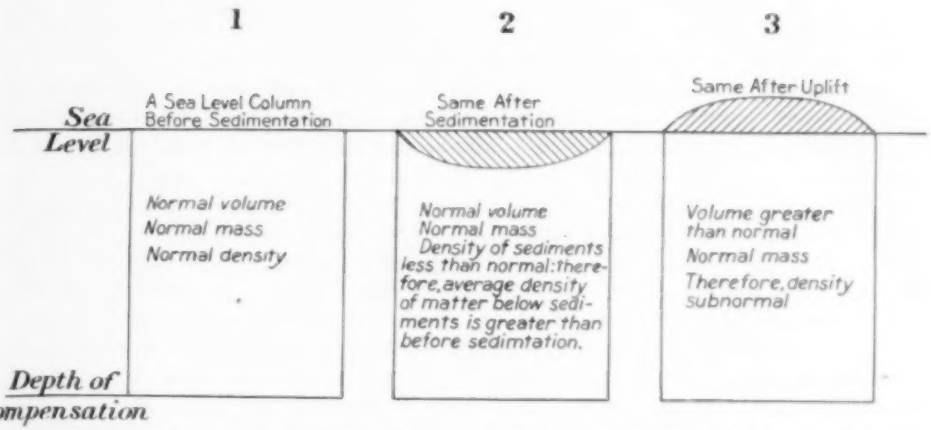

FIG. 5. THE EARTH'S CRUST IS IN EQUILIBRIUM, AND PROBABLY ALWAYS HAS BEEN SO. ASIDE FROM DEPRESSION AND ELEVATION INCIDENT TO SEDIMENTATION AND EROSION, CHANGES IN THE ELEVATION OF THE EARTH'S SURFACE ARE DUE TO CHANGES IN DENSITY IN THE CRUST.

percentage as the weight of any other unit block; the mass represented by land which is above sea level is balanced by a material lighter than the average in the crust below, just as a portion of an iceberg above water is floated by the part which is below; no mass above sea level equal to a disk of rock twenty miles in diameter and three thousand feet in thickness fails in being compensated by deficient density in the crust beneath it; the water in the oceans is compensated by material denser than the average in the crust below the oceans; unit blocks under land areas of various elevations and blocks under the oceans of different depths are in equilibrium; blocks under the oldest and under the most recent geological formations are in equilibrium, as well as the blocks under the areas of intermediate geological ages.

The work done by the U. S. Coast and Geodetic Survey has been supplemented by that of the Survey of India, which has done some notable work in testing the theory of isostasy. Its results have been published in several official reports and papers in scientific journals. The most noteworthy of these are by Colonel Sir Sidney Burrard,[6] formerly surveyor-general of India.

Some studies which will show the degree to which the theory of isostasy obtains for the areas of other countries are under way, and it is hoped that reports will soon be made of the results.

So far, we have been on sure ground. Hayford, Burrard and the writer agree and their views are supported by many others as to the existence of the isostatic equilibrium of the earth's crust in the United States, a part of Canada and in India. Since this is true of these large areas it is perfectly logical to conclude that it is true of the rest of the crust of the earth, whether land or the ocean areas.

From this point we must use indirect methods and inferences in interpreting the significance of the theory of isostasy.

[6] Colonel Sir Sidney Burrard, "Isostasy in Himalayan and neighboring regions," Prof. Paper No. 17, Trigonometrical Survey of India; "A brief review of the evidence on which the theory of isostasy has been based," *Geographical Journal*, London, Vol. 56, July, 1920; and "On the origin of mountain ranges," *Geographical Journal*, September, 1921.

Some of the results[7] of the writer's investigations diverge greatly from the generally accepted theories regarding the constitution of the earth's crust and the processes which have so altered the appearance of its surface during geological times.

The earth's crust is very weak as a structure, and does not stand up as a masonry arch carrying great loads as extra weight. If it were very strong small blocks of it would not have the same mass or weight. Tens of thousands of feet of material have been eroded from some areas as, for instance, those occupied by the Appalachians and the Himalayan mountains. The blocks of the earth's crust under these mountains are not extra light. The materials eroded from the mountains have been carried by streams and rivers either to great valleys or to the edges of the continents and have been laid down as beds of sediments tens of thousands of feet in thickness, but the blocks of the crust under the sediments are not extra heavy.

Would not any one, considering the evidence, reach the conclusion that the blocks under the sediments sink under the added load and that the blocks under the mountains rise as materials are worn away from their surfaces? This is exactly what must happen, but how can this come about? The answer is that below the crust, something more than sixty miles below sea level, the earth's materials act as if they are plastic and are readily moved sideways when the blocks of the crust are loaded and unloaded.

There are really no such things as blocks of the crust, for the crust is solid and continuous over the whole earth. But the assumption of separate blocks helps one to study the conditions and processes, while without this assumption one would be led into much difficulty and confusion.

The material below the crust must be much hotter than that at the surface, and the lower material is under a weight of about fifty million pounds or twenty-five thousand tons per square foot. We do not know the temperature; in fact, by direct observations and measurements we do not know anything about the earth at a lower depth than about one and one half miles. Borings have been made to that depth, and they give an indication of the change in temperature down in the crust. It has been found that the temperature increases at the rate of about 50° C. to the mile. If this rate of increase were uniform, we should have a temperature of about 3,000° C. at the bottom of the crust, a temperature which at the earth's surface would be sufficient to fuse rocks of all kinds. Owing to the great pressure exerted by the crust, even the great temperature which must be below can not fuse the rocks. In fact, the inference from tidal, earthquake and latitude observations is that the material below the crust is as rigid as steel. This inference or conclusion has not been questioned. How can this material be so rigid and yet yield to the loading and unloading of portions of the crust? Here we must bring in the time element. The stresses resulting from the tide-producing forces of the moon and of the sun, the earthquake vibrations and the forces which produce variations in latitude act for very short times, for a few minutes or hours or for a day or a year. To these short stresses the material below the crust acts as a rigid body. However, the stresses resulting from the disturbances of gravitation act for thousands of

[7] William Bowie, "Some geological conclusions from geodetic data," Proceedings of the National Academy of Sciences, January, 1921; "The relation of isostasy to uplift and subsidence," *American Journal of Science*, July, 1921; "The earth's crust and isostasy," *Geographical Review*, October, 1922; "Yielding of the earth's crust," Annual Report, Smithsonian Institution, 1921.

years. To these long-continued stresses the material is plastic and yielding.

A tallow candle can be snapped by the application of a sudden strong force, but it will be bent without fracture by a small constant pressure. Every one knows how easily glass is broken, but put a long piece of glass on two supports and leave a weight on its center for a month or two and the result will be a decided bending downward. There is really no material which can not be distorted without rupture under force applied under certain conditions for a sufficient time. We may accept as an entirely logical deduction that the material under the crust is plastic to even small stress differences caused by the movement of material by streams and rivers over the earth's surface. By small I mean the equivalent of five hundred or a thousand feet of material, deposited over or eroded from an area one hundred or two hundred miles square.

Suppose two piles of boards were placed on a flat of soft mud. Each of the piles would sink to such a depth that the weight of the displaced mud would equal the weight of the pile. Suppose further that a layer of boards were taken from one pile and placed on the other, then what would happen? The first pile would rise, while the second one would sink deeper, but the surface of the first pile would be slightly lowered, for the mud coming under the pile would have a less thickness, since its density is greater, than that of the boards removed. On the other hand, the surface of the second pile would be raised a little by the addition of a layer of boards, for the mud pushed from the bottom would have a thickness less than that of the boards. At first there would be some disturbance of the hydrostatic balance of portions of the mud flat by the transference of the boards from one pile to the other, but after a few days or weeks the balance would be restored.

The earth's crust acts somewhat in accordance with the crude illustration of the piles of boards resting on or in the mud flat. But with the crust we must have a longer unit of time, a thousand or even ten thousand years. The sinking of one block of the crust under sediment will push the suberustal material towards the blocks undergoing erosion, thus restoring the isostatic balance.

With a weak crust and plastic material below, how could the crust accumulate stresses for ten or a hundred million years due to a cooling and shrinking nucleus resulting later in convulsions which would form mountain systems by collapse of the crust and the crumpling of its materials? This is the theory of mountain building held by many geologists of the present and most of those of earlier times; it does not appear to be in accord with our present-day knowledge of the earth's crust.

The geological estimate of the time since the oldest existing sedimentary rocks were formed is about one and one half billions of years.

Sedimentary rocks result from the action of water, therefore the temperature of the earth's surface one and one half billions of years ago must have been less than 100° C. Before there were sediments, water could not have been running over the surface of the earth. The inference must be that the surface materials were hotter than the boiling point of water.

The temperature at the surface of the earth varies with the season of the year and the latitude, but the average for all land areas for a year is between 5° and 10° C. Assuming 10° C. as the temperature of the surface, then the drop during one and one half billion years is only about 90° C. If all the change could have taken place at once, the shortening of the diameter of the earth would have been about two miles and the circumference would have been lessened by only

about six miles. These changes are insignificant as compared with the great contraction of the crust since the beginning of sedimentation, computed by some geologists.

Below the sedimentary rocks which enfold the earth there are what are called igneous rocks, which presumably were fused at some very distant time. Let us assume that they were. At that time the surface temperature must have been more than 1,000° C. This temperature had to fall to the 100° C., which occurred about one and one half billion years ago. From the time that the earth's surface was molten to the time when the oceans were formed there must have elapsed many years, possibly from ten to twenty billion, during which the surface cooled to 100° C., if the rate of cooling were the same as during the last billion and a half years.

The above is a very important deduction, for it indicates that the earth's materials had enough time to do all the contracting possible under gravitational forces prior to the beginning of the sedimentary stage of the earth's existence. There may have been other sedimentary periods in the dim past, but if so no record of them has been left us.

The theory of the contracting nucleus and the collapsing crust as the cause of mountain building should be abandoned. It does not fit the accurate geodetic data, nor can it stand the usual processes of physical reasoning.

We have, then, a solid but weak crust, and an interior rigid to stresses of short duration but plastic to stresses acting through geological time. It has had sufficient time to assume a state of equilibrium under the gravitational forces exerted by its own material. Great changes in elevation of the surface materials have taken place.

What, then, are the primary causes of the surface disturbances? By a process of elimination we arrive at the conclusion that the causes are water and gravitation. The moisture falls from the air as rain, and the water runs over the land area from the high ground to the seas and oceans, carrying vast quantities of solid matter in suspension and solution. This material is deposited as sediment in the valleys, at the continental margins and out in the oceans. Gravitation makes the water flow down the slopes, it forces the crust down under the weight of the sediments and it forces up the lightened crust where erosion has occurred.

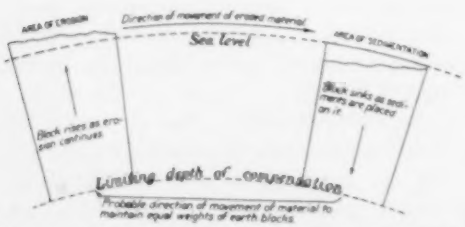
AREA OF EROSION
Direction of movement of eroded material
Sea level
AREA OF SEDIMENTATION
Block rises as erosion continues
Block sinks as sediments are placed on it
Limiting depth of compensation
Probable direction of movement of material to maintain equal weights of earth blocks

FIG. 6. THE ACTIVE AGENTS DISTORTING THE EARTH'S SURFACE ARE WATER AND GRAVITATION. THE WATER FALLING ON ELEVATED GROUND ERODES THE SURFACE AND CARRIES THE MATERIAL TO LOWER GROUND. GRAVITATION CAUSES THE WATER TO FLOW TO THE OCEANS AND IT FORCES THE CRUST DOWN UNDER THE LOAD OF SEDIMENTS AND UP WHEN EROSION HAS LIGHTENED IT.

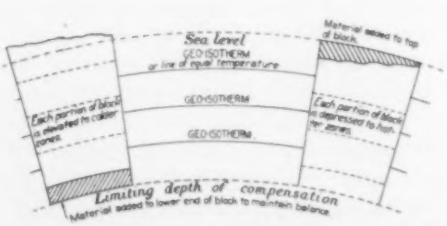
Material added to top of block
Sea level
GEOISOTHERM
or line of equal temperature
GEOISOTHERM
GEOISOTHERM
Each portion of block is elevated to colder zones
Each portion of block is depressed to hotter zones
Limiting depth of compensation
Material added to lower end of block to maintain balance

FIG. 7. DURING THE ELEVATION OF A PORTION OF THE EARTH'S CRUST UNDER AN AREA OF EROSION, EACH PART OF THE UPMOVING CRUST GOES TO A REGION OF LOWER TEMPERATURE; WHILE UNDER ACCUMULATION OF SEDIMENTS EACH PART OF THE CRUST BENEATH IS LOWERED TO REGIONS OF GRATER TEMPERATURE. THE CONSEQUENT HEATING AND COOLING CAUSE CHANGES IN VOLUME WHICH RAISE OR LOWER THE EARTH'S SURFACE.

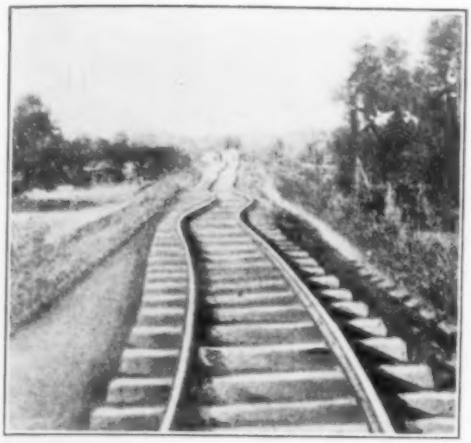

FIG. 8. THE VIBRATION OF THE EARTH DURING AN EARTHQUAKE IN JAPAN THREW A STRAIGHT PIECE OF RAILROAD TRACK OUT OF ALIGNMENT. THESE VIBRATIONS SHAKE TO PIECES POORLY CONSTRUCTED BUILDINGS.

The average rainfall now over land areas is about two and one half feet per year. This means a mile of rainfall in about two thousand years. Some places have much greater rainfall, while others much less. Should the rate of rainfall have been constant during the sedimentary age of one and one half billion years the total rainfall would have been more than one half million miles. This great rainfall has been the ultimate cause of mountain formation and the great changes in the earth's surface. It produces all the force necessary, as it runs from the land to the sea, to lift up new mountains and wear away old ones.

A mountain system, once formed, tends to retain its elevation, as the isostatic adjustment forces suberustal material under the base of the crust and pushes the eroded blocks up. However, the mountain system will be gradually worn down, for the materials entering at the bottom are denser than those of the eroded matter. If this difference were 15 per cent., then it would be necessary to erode away about seven times the thickness of the material that was above sea level when the mountains were first formed, in order to bring them down to sea level. Thus, to level an uplifted area five thousand feet in elevation it will be necessary to carry away about thirty-five thousand feet of material. We get here the answer to the question of how granite masses, which were formerly below the sediments and even several miles below sea level, can now be thousands of feet in the air as rugged mountain peaks.

During the process of uplift, to restore the isostatic equilibrium disturbed by erosion, there is great distortion of strata with folding, horizontal thrusting, crushing and crumpling, the results of which can be seen in any mountainous area. This wrecking of the strata has been held by many to have been caused by the collapse of the crust as the nucleus shrank away from it, and that all the distortion occurred during the first

FIG. 9. THE CALIFORNIA EARTHQUAKE OF 1906 CAUSED PERMANENT HORIZONTAL MOVEMENTS OF THE GROUND. THE FENCE SHOWN HERE WAS BROKEN AND OFFSET A NUMBER OF FEET. THE HOUSES NEAR BY APPEAR TO HAVE WITHSTOOD THE SHOCK.

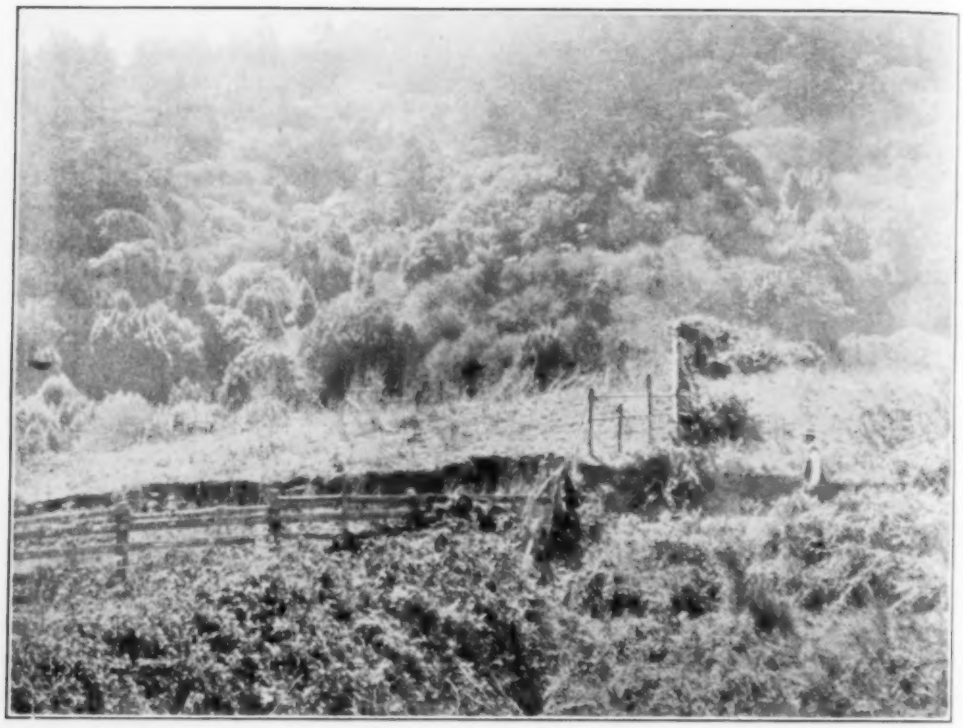

FIG. 10. HORIZONTAL AND VERTICAL MOVEMENT OF THE EARTH'S SURFACE NEAR BONDIETH'S RANCH DURING THE EARTHQUAKE OF 1906. HORIZONTAL DISPLACEMENT IS SHOWN BY THE FENCE WHICH HAD BEEN REPAIRED.

uplift. I think the theory outlined above is simpler and more logical than the collapse theory.

Now let us see what is happening where the sediments are deposited in beds ten thousand feet or more in thickness, such as are found at the mouths of great rivers and in plains like those through which flow the Ganges and the Indus rivers in India.

As the material carried by the rivers is deposited, the crust beneath sinks under the load, each part of the crust sinking to regions of higher temperature than that of its original position. But not all the depression is due to the weight of the sediments. As they are lighter in density than the material pushed away from the base of the crust, they would soon pile up so high that the river carrying the sediments would flow off to some other place. Ten, twenty or thirty thousand feet of sediments could not be laid down unless there were an independent contraction of the material of the crust. This contraction would increase the density of the material, and with the lighter sediments would maintain the isostatic balance. Of course during all this process a mass equal to that of the sediments would be pushed away from the base of the crust affected. However, if the sediments were laid down in very deep water, great thicknesses could be deposited without the necessity of having an independent shrinking of the crustal material.

The shrinking of the material of the crust seems to be an after-effect of the rising of the crust under areas subjected to heavy erosion. To restore or to maintain the isostatic equilibrium as the material is eroded away from the surface of a high area, material is brought into the base of the crust below. Each portion affected is carried to regions of lower temperature, and the imaginary surfaces of equal temperature, called geoisotherms, are raised above their usual positions in the crust. In spite of the fact that the wearing down of an elevated region by erosion requires many years, probably millions, the depression of the geoisotherms to their normal positions through cooling probably takes a much longer time. As the material of the crust loses its heat, it undergoes thermal contraction, and probably also a contraction due to molecular changes, thus depressing the surface even below sea level. It seems probable that great geosynclines or troughs in which the rivers deposit their sediments are started in this way. This shrinking continues, even during the early stages of the sedimentation, and thus we have the shrinking or contracting of crustal material under the active sedimentary regions.

The sinking of the crust, under the weight of the thick beds of sediments, will make the material of the crust move to regions of greater heat, thus depressing the geoisotherms, and some time after the sediments have been deposited to a thickness of from ten to thirty thousand feet the material of the crust will become heated many degrees and will expand. This expansion will be partly the usual thermal expansion, such as we see in the mercury of a thermometer, but, in addition, there will be an increase in volume and decrease in density from molecular processes. This expansion

FIG. 11. EARTH MOVEMENT NEAR OLEMA, CALIFORNIA, DURING QUAKE OF 1906.

FIG. 12. FUJIYAMA, THE SACRED MOUNTAIN OF JAPAN, IS AN EXTINCT VOLCANO. TO AGREE WITH ISOSTASY THE LAVA FORMING THE PEAK MUST HAVE ISSUED THROUGH A CRACK IN THE OUTER ROCKS OF THE EARTH. THE MASS OF THIS, AND OF OTHER MOUNTAINS, ARE NOT EXTRA LOADS ON THE BASE OF THE CRUST BENEATH.

will cause the surface of the crust to rise and to form a mountain system or a plateau.

It would appear, from the foregoing, that we have a theory regarding the great upward and downward movements of the earth's surface connected directly with changes in density and in volume. These changes are due to changes in the temperature of the crustal material, as water and gravitation shift loads over the earth's surface. This theory is in harmony with the geodetic and geophysical data resulting from accurate observations.

According to the new theory the principal causes of earthquakes are the sinking of the earth's crust under sediments, the rising of the crust under areas of erosion and the expansion of the crust following great accumulations of sediments. The earthquake is merely a symptom of something more fundamental taking place in the earth's crust. It is the effect rather than the cause, just as we may say that for a human being the chill is a symptom of malaria rather than the disease itself.

They can be predicted as to time and place, but the strength of the quake is uncertain, the element of time is long and the place is large. We may say with some certainty that there will be an earthquake in California during the next week and it is practically certain that it will occur. This statement is based on the fact that there has been, each week during past years, a recorded earthquake shock, or at least one would have been recorded had there been a sufficient number of recording stations in the state of California. They vary

greatly in intensity. In 1906 an earthquake occurred near San Francisco, causing great destruction of property. Within the last year an earthquake occurred in southern California which caused grat damage. Many earthquakes have occurred which were felt by man, but which caused no material damage. However, by far the greater number of earthquakes have not been felt by human beings but have been recorded on the very delicate instrument called the seismograph.

We may predict that, within the next century, a heavy destructive earthquake is likely to occur along the Atlantic coast. This is a logical deduction from the fact that, in the early part of the last century, there was a destructive earthquake in New England, and in 1886 there was a destructive earthquake in Charleston, South Carolina. We may predict, however, with reasonable certainty of fulfilment that there will be an earthquake on the Atlantic coast within the next five years; this is based on the evidence that many have occurred along the Atlantic coast during recent decades, some of which have been felt but most have only been discovered by the seismograph records.

It also seems to be reasonably certain that we shall have a heavy earthquake sometime in the future in the Mississippi valley, for, in 1811, there was a very destructive earthquake in the vicinity of New Madrid, Mo.

While we may predict an earthquake for a certain general region, it is a very much more difficult matter and may be impossible to make a prediction for a small area such as that covered by a city or even a county. In fact, one would be rather bold who would say that any one city in the United States is likely to have an earthquake of a destructive nature within any given period of years, no matter how great.

With the accumulation of accurate earthquake data the prediction of earthquakes in the future can be made with more accuracy than now.

All great mountain systems have been created by the uplife of vast amounts of sediments. This is the reason why mountain chains skirt the margins of continents and former inland seas. Those are the regions where the thickest deposits are laid down.

Volcanoes are active only along chains of islands and in new mountains in the process of formation. Is it not probable that they are merely incidental to the uplifting of the areas, resulting from the expansion and movements of the material of the crust below?

It seems to be probable that there were no mountains on the earth before water began moving materials from place to place over the surface, but it is probable that the surface had great irregularities. This is a perfectly logical deduction from the results of important investigations made by Dr. Henry S. Washington, of the Geophysical Laboratory of the Carnegie Institution of Washington. He has found that the igneous rocks, usually deep seated but now exposed at the surface, have densities derived from their chemical composition, which bear very definite relations to the elevations of the areas where found. The igneous rocks of the continents are found by him to be lighter than those of oceanic islands. Is it not probable that, before the sedimentary age, the earth's surface was irregular, with the areas underlaid by lighter rocks standing higher than those above denser and heavier rocks? If this is true, then water, falling from the atmosphere to the earth and seeking its level, collected over the heavy areas, thus forming the oceans.

Washington's discoveries enable us to account for the presence of continents

and oceans. It is probable that they maintain their relative positions, although parts of them are affected by uplift and subsidence, due to the transference of eroded material followed by changes in volumetric densities of the crustal material.

What caused the lighter rocks to congregate in some parts of the crust and the heavier rocks in others is one of the great earth mysteries concerning which no one has yet offered a satisfactory explanation.

The geological history of the outer portion of the earth for the last billion and a half years or so is written and recorded in the sedimentary rocks. It is written in a strange language, and many have been the attempts and many the failures to translate it. This is not to be wondered at, for while some chapters remain intact some have been buried from sight, some have been entirely lost and still others are badly torn as a result of the unceasing action of water and gravitation and their consequences. But we are able to make accurately at least a partial translation, by means of the alphabet furnished by the geodetic, geophysical and geochemical data collected in recent years.

WHY WE SHOULD BE MORE INTERESTED IN NUTRITION

By Professor VICTOR E. LEVINE
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THE age in which we live marks the beginning of many departures from the past. It is an age in which more and more attention is being focused upon the individual human being. Civilization is entering upon a period of humanization. This tendency is well marked in many lines of endeavor, but it is especially to be noted in science. Heretofore science concerned itself mainly with branches more or less of an impersonal nature, as astronomy, geology and mathematics. Even chemistry and physics occupied the attention of the chemist and the physicist for the sake of these sciences alone. It was a period of science for the sake of science, and there was a marked differentiation in so-called pure science and in applied science. To-day even pure science is turning sharply its worthwhile efforts in the direction of applications mankind can make from its marvelous findings.

We are beginning to realize that the proper study of mankind is the human being, just as in biology the study of the cell is regarded as the key to the knowledge of the workings of the complex biologic organism. There is more or less a feeling that all useless science is an empty boast. The tendency toward the direct application of science to the problems and to the welfare of the human being constitutes, indeed, a great advance in our mode of thinking. It is this change in viewpoint, the directing of our efforts toward the betterment of the individual, toward the development of a higher type of human being that has brought forth great progress in such sciences as anthropology, sociology, economics, psychology and also preventive medicine, which concerns itself with the health of individuals, of communities and of nations. The greatest scientific achievement of the age is not the automobile or the photoplay or the aeroplane or even the radio. It is the saving, thanks to the progress of preventive medicine, of the lives of millions of our most precious possessions—our children.

When men of science turned their guns upon the individual they were much surprised to find that they lacked even the elementary knowledge of some of the most essential things that concerned him and the things nearest him. They realized but too well that in the past they looked for gold in fields far away and that the advice of Socrates, "Know thyself," was more honored in words than in actual observance. The lack of knowledge was very apparent in reference to nutrition, that is, in reference to the science of food and feeding. Experts in this particular field of public health were much surprised themselves to find that most of our knowledge relative to nutrition was more or less handed down to us in a traditional way and that a good deal of that knowledge was fundamentally wrong, being based upon opinion, which experimental facts and the experience of the race could not justify.

Nutrition is becoming more and more recognized as one the most fundamental factors in the problem of private and

public health. We are fully aware that man does not live by bread alone and that he does not live in order to eat; but at the same time we must realize that our bodies are what we put into them and that a great many ills, both minor and major, depend upon some dietary indiscretion or some dietary insufficiency. These we shall discuss at some later date.

Not only scientists and welfare workers, but even poets recognize the importance of nutrition. Take Byron, for example, who, in his poem "Don Juan," proclaims:

> All human history attests
> That happiness for man—the hungry sinner,
> Since Eve ate apples, much depends on dinner.

Nor is Byron the only poet who realizes the value of nutrition. Owen Meredith, although a little gloomy about friendship and poetry and music and art, places cooking and dining upon quite a high pedestal. Hear his words:

> We may live without poetry, music and art;
> We may live without conscience, and live without heart;
> We may live without friends, we may live without books;
> But civilized man can not live without cooks.
>
> He may live without books—what is knowledge but grieving?
> He may live without hope—what is hope but deceiving?
> He may live without love—what is passion but pining?
> But where is the man that can live without dining?

Is Instinct a Safe Guide to Nutrition?

We have just pointed out the fact that modern scientific research has for its ulterior and highest motive the improvement of the race through the individual human being. Heretofore civilization focused its efforts upon building through the development of institutions. The individual as such was not concerned in the plan. That this type of civilization has much in it to be regretted is best expressed in the language of Edwin Markham, the Abraham Lincoln of American poetry:

> We are all blind until we see
> That, in the human plan
> Nothing is worth the making, if
> It does not make the man;
> Why build these cities glorious
> If man unbuilded goes?
> In vain we build the world unless
> The builder also grows.

This turning of the limelight upon the human being as the important building stone of society has resulted in remarkable progress and new viewpoints in the subjects concerning him, such as psychology, sociology and public health or hygiene, of which nutrition is a part.

There was a time when nobody even thought in terms of health. Pain or fear drove many a person to the nearest physician for relief. He became a patient and there ended his responsibility. Modern humanized science has made us realize the extreme value of the age-old, half-accepted, half-rejected idea that an ounce of prevention is better than a pound of cure.

Many of us will ask the question, Why worry about nutrition at all? Does not instinct guide us through appetite into proper choice of food? So do many of us believe. But one of the misconceptions that is dying a slow death involves the relation of instinct to the proper choice of food. Some contend that it is not necessary to worry about our nutritional requirements, since the good angel, instinct, is ever on guard duty to protect us. This idea does not hold up under actual experimentation and observation. Modern nutrition demonstrates clearly, especially in reference to the human being, that instinct is not a safeguard to proper feeding. Modern science has taught us that while instinct preserves us from a great many pitfalls,

it surely does not prevent us from loading our systems with foods improper for growth or for maintenance of health and vigor. A quotation from a poem will bear out this point in a rather humorous way:

'Tis not her coldness, father,
That chills my laboring breast,
It's that confounded cucumber
I've ate and can't digest.

One of the greatest advances in modern nutrition lies in a realization of the fact that instinct or appetite is not a guide to proper feeding. Often it is taste; most often it is habit. As for taste, the professional cook can so pepper and salt and season an ancient steak as to give it the appearance and flavor of youth. How often do you read in the daily newspaper of people dying of food poisoning resulting from a carefully prepared meal of which they partook at some social dinner or in some very beautiful dining room of a modern hotel!

In the ages beyond history we find the Neanderthal man of some fifty thousand years ago, the reindeer man of some thirty to fifteen thousand and the Neolithic man of some ten thousand years back. These ancient sires no doubt relied completely on instinct for preservation of self and race. Through the thousands of years, into the biblical days and way up to the threshold of the industrial revolution, only some one hundred years ago, man practically led the same life and ate the same way. During these long years human intellect was in the process of development. Mind, indeed, made progress, but it was at the great expense of instinct. Among other things man lost his keen sense of smell, vision and hearing. When the industrial revolution began to make itself felt in relation to food supply, the human being had lost his instinct for the selection of natural food, and he began, without question or doubt, to make use of foods industrialized, commercialized; demineralized, devitaminized, devitalized; colored, bleached, dyed; smoked, heated, boiled, cooked, fried; polished, extracted, concentrated, distilled; preserved, pickled, canned, refrigerated.

Strange to say, not instinct but habit is the most important factor in appetite. We like the foods which we have been accustomed to from early years. We rave about the kind that mother used to make. The Irish like their potatoes; the Jews, their gefüllte fish; the Italians, their macaroni; the Scotch, their oatmeal; Mexicans, their chili con carne; the Japanese, their rice cakes. In the southern states people like bread made of cornmeal. Those who grow up on cornbread learn to like it. During the great war the French people could not accustom themselves to eat corn even under the pressure of lack of food.

The first woman who secretly introduced to her neighbors the delights of sauerkraut and dill pickles and the person who invented the "hot dog" were indeed individuals of no mean courage. The first man who ate eels was looked upon with considerable suspicion. Had neurological institutions existed at the time, he would no doubt have been held for further observation. The first man who swallowed an oyster performed as great a feat as the most daring vaudeville acrobat.

Some people find certain kinds of cheese outside the pale of polite society, though other folks rave about them. As a matter of fact it requires special training, not of stomach but of mind, to be able to eat certain dairy preparations labelled "cheese." Wines Spaniards care for are not palatable to Italians, and the wines of the Italian strike horror to the polite taste of the Spaniard. Beer is drunk everywhere in Europe, and in America whenever and wherever it is obtainable. When it was first introduced into Italy from Germany, many Italians found themselves unable

to comprehend how any one could drink it and at the same time pretend it was pleasant. The question at one time arose in Rome whether it was permissible to take beer on fast days. The cardinals who tasted it proclaimed that not only did it seem permissible but that it was a mortification to drink it, and that it was therefore a proper Lenten exercise.

Personal habit dictates our likes and dislikes with reference to food. Eating too little or too much is also a matter of habit. It is true that some people have an idiosyncrasy towards certain foods. We will soon speak of idiosyncrasy as food allergy. But by far the greatest number of food dislikes are based entirely upon subjective feelings, which can be overcome by habit and training. Some people have a natural repugnance for a very nutritious article of food, like eggs. That this feeling is subjective is evident from the fact that the laity have many opinions about the egg. Some say it makes them bilious, whatever that means. Some say it is too heavy for them; some find it distinctly constipating. Others claim that it has a marked tendency to develop diarrhea. Yet people who come into a tubercular sanitorium with an unreasonable disinclination for eggs soon learn to like them to the extent of taking a half a dozen or more daily.

Custom is also responsible for a great many dietary peculiarities. In some places the kidney and the liver are eaten with relish. The French like brains and other special parts. What are dainties to some people are repulsive to others. The Anglo-Saxons, as a rule, stick to muscle cuts of meat. McCollum has shown that this type of animal food is, however, by no means as nutritious as the organs like the liver, spleen, lung and other internal parts. But as a rule they are not used, for we lack the accustomedness to them. To the great majority of mankind the idea of eating horseflesh is repulsive, yet numbers of people in various parts of Europe have conquered the initial repugnance and are finding this animal food quite as pleasant as cow's meat. Snail soup is relished in Italy, while down at Marseilles gourmands feast on angle worms and find them appetizing.

The Chinese and Japanese prefer rice to wheat as a food grain. They seem to like polished rice even better than unpolished rice. We know that polished rice is injurious to health. Instinct should have demanded unpolished rice, since the polished grain leads to a very fatal disease called beri-beri.

We all know that carbohydrates, that is, sugars and starches, are very important in our diet. Lack of carbohydrate in the diet leads to serious disturbances, which may even result in death. The Eskimo diet is very rich in protein foods and fat and is extremely poor in sugar and may entirely lack starch. Yet it is surprising to learn that sugar is much disliked by Eskimos and that it takes a long time before they get used to it. We consume far too much salt in our diet. The Eskimo, on the other hand, gets just enough salt from his food without having recourse to the use of table salt. Yet the Eskimo gets used to salt more quickly than to sugar.

To show you the importance of habit again, we wish to mention that Eskimo dogs brought up on seal meat would have no other meat, even though they may be suffering from extreme hunger. In our laboratory we have often seen albino rats refuse food for days or eat very little of a new dietary mixture equally as adequate as the one to which they have been accustomed. Europeans who have never eaten bananas or tomatoes find them tasteless and disagreeable. It takes some time before they get up any enthusiasm for the tomato in spite of the fact that it is a very superior food, being rich in three important nutri-

tional ingredients—iron, vitamins and roughage. Next to the orange the tomato juice ranks in importance as a preventive of a disease of childhood and of adult life known as scurvy.

From what has been said it seems imperative for us not to overlook the importance of habit in medical treatment. Abrupt change in diet does not seem to go well with many people. Lack of appetite and even serious gastro-intestinal upsets arise. Individuals away from home often find themselves in constipation or in diarrhea for some time before they get accustomed to a new dietary régime. Perhaps this preliminary mal-adjustment is mental or it is the result of a disturbance in the physiological rhythm of the gastro-intestinal mechanism. This disturbance may be in the nature of a very slight allergic shock, which disappears as soon as the stage of desensitization is reached. In the treatment of many chronic conditions, such as those involving gastro-intestinal, cardiac or renal derangement or in diabetes, better results may be obtained in some cases or in many cases by making gradational the changes in diet necessary to approximate it to the contingencies of the given pathological condition.

That appetite is not a safe guide to the body's need is seen from the fact that many people eat too much protein or use too much carbohydrate. Modern medicine teaches us that excessive protein as is found in such food as meat may lead to a deterioration of the kidney and may result in derangement of its functions, giving rise to nephritis. Modern medicine also teaches us that excessive use of sugars and starches may so overwork one of the organs, the pancreas, that diabetes may be the outcome.

That appetite is not an index to the body's need for food is again seen in the prevalence of fat persons. Certain types of overweight are due to excessive food intake. The statistics of life insurance companies and the experience of physicians indicate that obesity is not an asset but a liability. Overly fat people have a much smaller chance in pneumonia or in heart disease than persons of normal weight.

Some people are very susceptible to certain kinds of foods. They suffer as a result of this susceptibility from gastro-intestinal upsets, from asthma, from skin outbreaks, such as eczema or urticaria, popularly called hives. This susceptibility is referred to as food allergy. Such innocent and simple foods as eggs, milk, beef, pork, beans, onions, cabbage, rice, tomatoes, strawberries, honey and others have been found to be the underlying cause of asthma, acute abdominal pain or skin outbreaks. Often the patient is aware of an allergic attack after eating certain foods and keeps away from these as a result of experience. Most often it is the physician who diagnoses the case by means of history or special skin tests and advises the patient to avoid the food responsible for this condition.

Still another example as to lack of relation between instinct and biological need we will take from the experience of mothers. It is a very easy matter to explain to a mother how a child should be fed in order to insure normal growth and development. It is not a difficult matter to convince mothers that these foods are needed, nor to arouse in them an interest and a desire to have their children living on such an adequate diet. But it is by no means assured that the child will be so fed. Here we may meet with a stone wall of children's likes and dislikes and mother's inability to alter them. You hear these expressions from mothers: "My child does not like milk. I can't make him eat. He hates the sight of vegetables." Many mothers already know what a child should be fed, but the all-absorbing question is, "How can I get him to eat it?"

The inability of instinct to serve as a guide also holds true for animals. We shall cite from some experiences of Professor Elmer V. McCollum, of Johns Hopkins. Young white rats grow well on a mixture of fifty parts corn meal, thirty parts alfalfa-leaf flour and twenty parts cooked beans. These may be ground together so finely that they must be eaten in the proportions given above. McCollum offered to growing white rats corn, alfalfa and cooked beans in separate dishes. They liked the taste of the corn better than the other two foods. They tried to live on corn alone, which in itself is not a very superior food, with the result that they grew less rapidly than the animals fed proper mixtures, were not so healthy, and did not possess the same degree of vitality.

To prove again that instinct does not always come to our defense in case of food we will cite another little anecdote. Charles Lamb, returning from a jolly dinner party, took his seat in a crowded omnibus. Shortly after, a portly gentleman put his head in and asked, "All full inside?" Lamb, who was nearest the inquirer, said, "I can't speak for the remainder of the company, sir, but as for myself, that last piece of oyster pie did the business for me."

Since the cues coming from our natural desires are misleading, we are impelled to seek through the experimental method information as to what constitutes adequate nutritional needs. Instinct will not guide us; food faddists mislead us; politicians and legislators do not understand, are indifferent to questions of public health or are engaged in the profitable pastime of vamping votes for an impending election. Our channel of knowledge is the scientist of the laboratory with his rats and his guinea pigs, the public health worker, the dietitian and the progressive, open-minded clinician at the bedside.

We must study food and food values and proper diet just as we must study history and geography, chemistry or mathematics. Since we can not rely upon instinct we are compelled to be seekers of knowledge in the field of nutrition.

As the problems of nutrition become better understood and more fully appreciated, the science will assume increasingly greater importance in the prevention and cure of disease, and consequently in the hygienic, social and economic uplift. From time immemorial nutrition has played a very prominent though unrecognized part in the story of man. Even in biblical beginnings, food seemed to be closely bound up with his physical and spiritual well-being. The records have it that it was woman who induced him to eat; he took to drinking of his own accord.

INFANT MORTALITY AND SURVIVAL OF THE FITTEST

By Dr. CHARLES HERRMAN
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THERE are two seemingly opposed views with regard to the advisability of reducing the infant mortality. One view is stated by Popenoe and Johnson as follows:

> Part of the children born in any district in a given year are doomed by heredity to an early death; if they die in the first year, they will not be alive to die in the succeeding year and vice versa. . . . If the gain is by great exertions made more than temporary; if the baby who would otherwise have died in the first months is brought to adult life and reproduction, it means in many cases the desemination of another strain of weak heredity, which natural selection would have cut off ruthlessly in the interest of race betterment. Insofar, then, as the infant mortality movement is not futile, it is, from a strict biological viewpoint, often detrimental to the future of the race.

Pearson, Snow and Ploetz have demonstrated by refined statistical methods that "a selective death-rate is strongly operative in man in the early years of life." The other view, which is held by Newsholme, Yule and others, is that "a high infant death-rate in a given community implies a general high death-rate in the next few years of life; while low death-rates at both age periods are similarly associated." . . . "There is a very high correlation between the amount of infant mortality and of mortality at ages one to five." Speaking of conditions in New York City, Dr. S. Josephine Baker says:

> One of the great objections that has been raised against any intensive child welfare work has been that it perpetuates the unfit. In order to meet this objection we have kept rather careful statistics in New York City with regard to the child after it has passed the age of one year. Five years after we began our work with babies, we began to watch the effect on the mortality of children under five years of age. We have found since that time that the mortality in this age group, under five years, has shown a decline that has been much greater than that in the group under one year of age. In other words, the children are not only alive and well at the end of their first year, but they continue in good health throughout child life.

There is nothing in this statement which is incompatible with the conclusion that natural selection is operative in the early years of childhood. Almost all the reduction in mortality has been due to improvement in the care and feeding of infants and young children. These factors are operative not only in children under one year but throughout childhood. As selection is more strongly operative during the first year, these factors would have a greater effect during the succeeding years. Pearson and Snow have had such a large experience in the handling of statistical matter that their conclusions can be accepted without hesitation. These two seemingly opposed views are in reality not incompatible. There are two distinct groups of causes of infant mortality: the one depends on the character of the germ plasm; the other is not primarily dependent on the germ plasm, but is accidental and therefore to a great extent preventable. To give an example: anencephaly is due to a defect in the germ plasm; death from cerebral hemorrhage in a newborn following a difficult labor, and possibly lack of skill on the part of the attending obstetrician is accidental and preventable. There are also some

deaths which are due to a combination of both causes. If a baby contracts an infectious diarrhoea as a result of drinking contaminated milk, whether it dies or succeeds in overcoming the infection will depend largely on its resistance; in other words, on the character of the stock.

Those who claim that the reduction of the infant mortality is not an unmixed blessing have in mind primarily the saving of infants who have defects in the germ plasm; those who hold that the results obtained by the infant welfare campaign are entirely beneficial are referring to the deaths which are primarily accidental and due to preventable causes. The dictum that "a high infant mortality results in the sacrifice of the unfortunate, not the unfit" should read, "a high infant mortality results in the sacrifice of the unfortunate *as well* as the unfit." It is sometimes said that some of our greatest men were weak and sickly infants and would have been lost to humanity if the eugenist had his way. Goethe and Newton are favorite examples. In his autobiography Goethe says, "These good aspects which the astrologers managed subsequently to reckon very auspicious for me may have been the causes of my preservation; for *through the unskillfulness of the midwife* I came into the world as dead and only after various efforts was I enabled to see the light." There is here no indication of a defect in the germ plasm; on the contrary Goethe fully appreciated the importance of descent from good stock, for he says in his well-known couplet that he obtained his good stature, his energy and earnestness from his father, and his lively disposition and imagination from his mother.

Natural selection is still potent. Of the neonatal deaths, approximately 75 per cent. are due to malformations and so-called congenital debility and are largely beyond our control. As will be seen by referring to the chart there has been little or no reduction in this group. In other words, the reduction has been for the most part in the group of causes not primarily of germinal origin. At the present time, in spite of all our efforts, the defective embryos do not reach maturity, or if they do mature, they die shortly after birth. We can not accept the statements that "a *few* causes of stillbirth depend on factors relating to the child itself," and "sixty-five per cent. of the deaths from congenital diseases under one month are preventable by means of prenatal care." Adequate prenatal care and improved obstetrics will markedly reduce the neonatal deaths due to syphilis, to the toxemias of pregnancy, to the accidents of labor; but there will still remain a large number due to defects in the germ plasma, which no amount of prenatal care, *as now carried out,* will prevent. It is possible that in the future we may be able to influence the character of the germ plasm during pregnancy; but at present the health of the newborn infant and the ability of the mother to nurse depend more on her health *before* than during pregnancy. Natural selection is operative in infancy and childhood. All children must pass through a series of severe tests. One is reminded of the cross-country-run of college boys. The contestants must overcome a variety of obstacles; they must struggle through thick brush; ford streams; climb over fences and crawl under nets. Only the sturdier reach the goal. About 15 per cent. of the fertilized ova perish; of those that mature about 5 per cent. result in still-births. Some must pass through the dangers of a difficult labor; later some find it difficult to cope with the hazards of artificial feeding and the heat of summer; so that by the end of the first year from 7 to 10 per cent. have succumbed. Still later they must overcome the infectious diseases of child-

hood, measles, whooping cough, diphtheria and scarlet fever, with their frequent complications. It has been estimated that not more than 60 per cent. reach adult life and leave offspring. Thus the least fit from a physical and immunologic standpoint are eliminated.

Among uncivilized tribes, as among animals in a state of nature, natural selection has full sway; the weak and deformed are killed or allowed to die; exposure or lack of food in times of famine or when migrating from place to place kills some of those who are fortunate enough to survive the first few years; disease does the rest; so that only the strongest reach maturity. In modern life, especially in our large cities, selection is still operative, but its methods are somewhat different. The weak are protected against the rigors of climate, provided with proper food and given the tenderest care; but the character of modern life produces more miscarriages, premature infants and stillbirths. More infants must be artificially fed, and still more important in our densely populated cities, there is much crowding, and as the communicable diseases are always present, contact infection is easy. The result is that practically all infants and young children contract these diseases sooner or later, and the most unfit from a *physical and immunologic standpoint* are eliminated. This is shown by the fact that there has been comparatively little reduction in the mortality from respiratory and infectious diseases. In connection with this discussion the following passage from Boswell's Johnson will be found interesting:

Boswell: "I believe, Sir, a great many of the children born in London die early."

Johnson: "Why, yes, Sir."

B.: "But those who do live are as stout and strong people as any. Dr. Price says they must be naturally strong to get through."

J.: "That is system, Sir. A great traveller observes, that it is said there are no weak or deformed people among the Indians; but he with much sagacity assigns the reason for this, which is, that the hardships of their life, as hunters and fishers, does not allow weak or diseased children to grow up. Now had I been an Indian I must have died early; my eyes would not have served me to get food. I must have starved or they would have knocked me on the head when they saw I could do nothing."

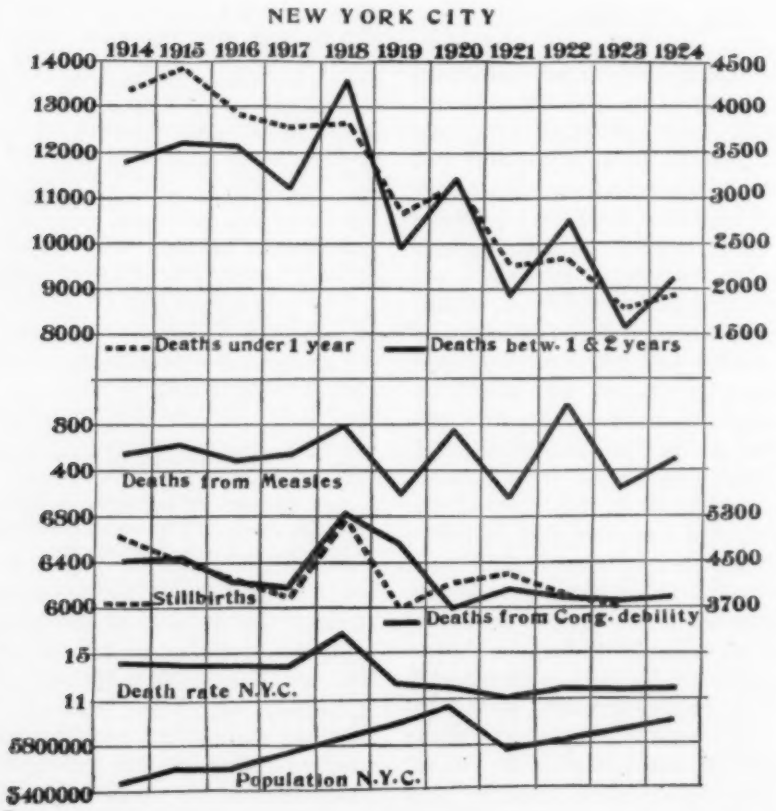
B.: "Perhaps they would have taken care of you. We are told that they are fond of oratory. You would have talked to them."

J.: "Nay, Sir, I should not have lived long enough to be fit to talk. I should have died before I was ten years old. Depend upon it, Sir, a savage when he is hungry will not carry about with him a looby of nine years old, who can not help himself. They have no affection, Sir."

B.: "I believe natural affection of which we hear so much is very small."

J.: "Sir, natural affection is nothing; but affection from principle and established duty is sometimes wonderfully strong."

Referring to the chart, certain features of the graphs will be noted, which suggest the action of natural selection. The population of New York City has increased only 9 per cent. during the last ten years, due principally to the absence of immigration during the European war and the restricted immigration since then. The number of births has decreased about 7 per cent. during this time, due principally to the well-known fact that the birth-rate is higher among parents of foreign birth. I have therefore found it simpler to use the number of deaths rather than death-rates. The death-rate between one and two years of age is estimated from the probable total population, so that it would not be more reliable. It will be noted that there has been a remarkable reduction in the number of deaths under one year and between one and two years of age; that when the mortality under one year is high in one year, it is low in children between one and two years of age in the succeeding year, and *vice versa*. This at least suggests the action of natural selection. In New York City measles is always present, and a very large percent-



age of all children contract the disease during the first five years of life. Almost all the deaths from this disease occur in children under five years, so that it serves as a very fair test of the resistance and the immunologic reaction of children. If we compare the deaths between one and two years of age with the deaths from measles we find a striking parallelism. This is not true of the other communicable diseases of childhood. The parallelism is not quite so striking under one year, because infants under five months are relatively immune to measles, and from five to eight months the disease is usually of a mild type; it is therefore only during the last four months of the first year that the disease is likely to be of a severe type, so that death results. Almost all the deaths are due to a complicating pneumonia, which kills those who are physically and immunologically below par. The year 1918 shows the selective action of the severe epidemic of influenza.

As there has been a decrease of 7 per cent. in the total number of births per year, we see that there has been no reduction in the number of still-births, or the deaths due to malformations and congenital debility. In other words, selection still eliminates those with defects in the germ plasm and those of low vitality. The reduction in mortality has been chiefly in deaths due to gastro-intestinal diseases, because here the chief causes, imperfect milk supply and ignorance in the care and feeding of infants, could be removed. There has been but little reduction in the deaths from in-

fectious diseases (except diphtheria) and respiratory diseases because the causative factors have been largely beyond our control.

Conclusions

The two seemingly opposed views with regard to the advisability of reducing the infant mortality are not incompatible. There are two distinct groups of causes of deaths in infants; the one group is due to defects in the germ plasm and destroys the weak; the other is largely accidental, affects the strong as well as the weak and is to a great extent preventable. The reduction in infant mortality has been almost entirely in the latter group. A high infant mortality sacrifices the unfortunate *as well* as the unfit. Natural selection is still operative. There has been no reduction in the number of miscarriages, stillbirths or deaths due to congenital debility. There has been very little reduction in deaths in infants due to infectious and respiratory diseases because these have been largely beyond our control. The health of the infant and the ability of the mother to nurse it depend more on the health of the mother before than during pregnancy. From the moment of conception children are subjected to a series of severe tests; only about sixty per cent. succeed in passing all these tests, reach adult life and leave offspring. In large cities with a congested population the infectious diseases, particularly those which attack the respiratory tract, are chiefly instrumental in eliminating the physically and immunologically unfit. Until we discover methods of influencing the germ plasm and immunizing against the infectious diseases, we shall not radically interfere with the operation of natural selection. By that time we shall probably have an intelligent appreciation of the importance of complete segregation of the unfit or possibly we shall have Haldane's ectogenetic mothers.

MIXING THE ISSUE IN IMMIGRATION

By Professor EZRA BOWEN
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PURELY qualitative changes in the affected populations are the most important result of immigration and emigration. Matter for deep concern, these inter-territorial human seepages, but thought trained upon their quantitative bearing is largely wasted, though all superficial evidence shouts, No—and arresting work has been carried through on that hallucinatory ground.

Between the sidewalk and the curb, in front of your house, there is a little plot of ground; overflowing foot traffic and a summer drouth have made it almost bare; a tuft or two in the most favored regions comprise the entire grass population. To improve matters, you throw a wire guard around it; you water faithfully, and add perhaps some grass food (fertilizer) to the earth. Weeks pass; and the original grass population has spread to the limits of the plot.

Instead of looking to the offspring of the original population to take up unoccupied regions, you might have sown strange seed—brought in the offspring of another plot, another land. In either case, the result is one—the choice has at least no quantitative bearing, though it will of course affect the breed. Had all immigration been cut off in 1850, the population of the United States would be, in number, exactly what it is;[1] this ancient contention now has marshalled behind it hosts of biologic and economic evidence. If an amelioration in living conditions warrants, population will increase and take up the slack. That this growth comes from immigration, increased birth-rate or decreased death-rate matters not; the quantitative result is in any case the same, and entirely the effect of more latitude in the conditions to existence.[2]

Short, sharp waves of immigration and emigration have important transitory by-products in unemployment, labor shortage and other discrepancies that are almost purely quantitative matters; but the main long-time currents of migration, which give the problem its constant features, produce almost purely qualitative changes. Let us instance a grouping of facts that brings into sharp relief qualitative changes resulting from migration:

PERCENTAGE OF POPULATION IN AGE GROUPS[3]

	1–15 years of age	15–65 years of age	65 years or more
United States	31.10	64.87	4.03
Massachusetts	27.10	67.88	5.02
South Carolina	41.60	55.50	5.90

[1] F. A. Walker, *Forum*, August, 1891. (The biologic principles involved are expressed best by E. M. East and R. Pearl in America and by J. B. S. Haldane and J. Swinburne in England. Whatever modification must be made, when we come to the human case in population, on account of the differential living-standard, is easily exaggerated. The standard of living of that purest of American strains, in the mountains of our southern states, reported by Professor Ross [cited below] is as low as that of any foreign-language group—and who, working in such groups, has not found that the assumption of the American living-standard by the newly admitted immigrant is frequently but a matter of months?)

[2] E. M. East, "Mankind at the Crossroads," 1923, Chapter IV.

[3] E. R. A. Seligman, "Principles of Economics," tenth ed., 1924, p. 56.

Make the center column the focal point of attention; then compare the second and third items with the first. In Massachusetts, persons of wealth-producing age are in abnormally high proportion: wealth-producing individuals form a much smaller proportion of South Carolina's population. Forty-five per cent. (persons too old or too young for economic activity) must, in South Carolina, ride upon the backs of the other fifty-five; but in Massachusetts the earners—sixty-eight per cent. of all—need support only thirty-two per cent. Many matters must be brought to bear in explaining the great wealth of Massachusetts and the comparative poverty of South Carolina—but the effect of migration is beyond a doubt one of them. Thousands of able-bodied young men, native whites, have left South Carolina's worked-out farms and timber regions; and thousands of able-bodied, young Europeans have swarmed into Massachusetts' mill towns. Many items must be taken into account in explaining the great wealth of the United States and the comparative poverty of Europe; but the economic blood of Europe has been losing steadily its red corpuscles, and the United States has gained them by transfusion.

Had restriction of immigration come fifty years ago, the population of the United States would be in number exactly what it is: had there been no emigration, the population of Europe would be no larger and no smaller than at present.[4] Migrations have no constant quantitative bearing. But immigration has kept the economic blood count of the United States well up; while in like degree the economic body of Europe has suffered from anemia—a momentous, wholly qualitative, matter.

An important genetic principle has a bearing here: The mixed breed is stronger, better able to cope with life, than the pure.[5] Who has not had a disastrous experience with one of those neurotic, inbred, Boston bull-terriers—his neighbor's or his own—tight little bundle of muscle and nerve with mottled-brown, twitching skin? In winter he is in the conservatory, the cat without; he races madly up and down, barking, whining and leaping against the pane, gaining nothing and finally becoming violently ill. In August his nerves blow up completely; he just misses inflicting probable death upon a neighbor's child, and the long arm of the law whisks him into the nothingness from whence he came. How different the common campus dog! Chest of a bull, lean clean legs, scent of a hound, his digestion is never disaffected, though his most regular diet be of grimy bits of half-soaked pretzel and an occasional boiled-out soup bone. Taking kicks and caresses philosophically, he is always serene. Just so with human beings: the mixed breed meets the bluff and guff of each new day more adequately than the pure. There is no such thing, of course, as a really pure human breed[6]—forever the waters have been mixing[7]—still, there have always been back-eddies where a small population swirls round and round, mingling only with itself, taking on a flavor uniquely its own. America has such back-eddies. In the present writer's county, Northampton, of Pennsylvania, lives a master carpenter whose family immigrated in 1641. Speaking English fatigues this man—German is the language of his recreating hours. Then there are those sinkholes of humanity in the mountains of Kentucky, North

[4] E. B. Reuter, "Population Problems," 1923, p. 195.

[5] E. Huntington, "The Character of Races," 1924, pp. 18, 19.

[6] E. Huntington, "The Character of Races," 1924, pp. 18, 19.

[7] J. A. Thompson, "Outline of Science," 1922, p. 1099.

Carolina, Tennessee[8] and in the pines of Southern New Jersey. Broader, of course, and less aggravated, still Europe is made up almost entirely of such whirlpools as these. There has been immigration and emigration from one European country to another; but here again America with her constant influx of new blood has had, for three hundred years, a great advantage—another far-reaching and purely qualitative bearing of migration.

But too much, or too rapid, mixing is also bad.[9] The skew faces and grotesque figures, common in every seaboard mill-town, are expressions of this principle.[10] Skew faces and grotesque figures, furthermore, may well be the outward and visible signs of an inward and spiritual distortion; for it is not quite clear whether thinking is done only in one specialized spot, the brain, or in every part of the body.[11]

Too rapid mixing means grotesque bodies, and there is apparent evidence for believing that this in turn indicates misshapen minds, distorted spirits. Moreover, man's anatomical integrity may be his most important asset. Of gorillas, 55 per cent. have seventeen spinal vertebrae; almost as large a proportion (40 per cent.) have sixteen; and 5 per cent. possess but fifteen. Man's structural integrity is far greater: ninety-six out of every hundred have seventeen spinal vertebrae; only a scattered few have eighteen; other counts are almost unknown.[12] Man is the animal of greatest integrity, the conserving animal—and this stability does not stop, of course, with vertebrae. Anatomical integrity is a tremendous human asset; one not to be squandered in too rapid mixing.[13] Here, America has had, in her flooding immigration, a very messy matter thrust between her hands.

A quickening of the currents of migration by the repercussions of a world war is everywhere in evidence. America has enacted under a mask of numerical quotas what is in form a quantitative, but in effect a qualitative immigration-restriction measure; the center of European emigration to the United States has been shifted sharply northward and westward. But the political impetus that put this bill through Congress sprang from a quantitative consideration: the labor vote wanted American jobs protected from an imminent influx of European jobfillers.[14] South American countries on the other hand encourage immigration to make good their labor shortages.[15] To fill their armies, European countries discourage emigration. Everywhere, quantitative considerations are uppermost and ruling. But this absorbing human question, this problem of migration, has been gripped wrong end to. Immigration and emigration, except for short sharp ebbs and flows, have no quantitative bearing; the problem they present is mainly one of qualities.

[8] E. A. Ross, *The New Republic*, January 9, 1924.

[9] J. A. Thompson, "Outline of Science," 1922, p. 1,000.

[10] E. A. Ross, *The New Republic*, January 9, 1924.

[11] H. C. King, "Rational Living," 1919. Chs. IV, V, VI, VII, VIII.

[12] T. W. Todd, THE SCIENTIFIC MONTHLY, December, 1924.

[13] E. G. Conklin, quoted in J. A. Thompson's "Outline of Science," 1922, p. 1,094.

[14] It is quite true that, during its pendency, intelligent discussion of this act centered upon its qualitative bearing, but intelligent discussion was not the force that carried it through Congress.

[15] William A. Reid, THE SCIENTIFIC MONTHLY, March, 1925.

THE SEARCH FOR THE MASTER KEY OF THE UNIVERSE

By Dr. DAVID STARR JORDAN
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A MASTER key opens all locks and solves all problems. Recent advances in knowledge have raised the question among certain scientific men as to which branch of research will first give us the master key to the universe. Shall we find it in astronomy or in physics?[1] Does the clue to infinity lie with the inconceivably great or in the impalpably small?

The astronomer points to the heavens crowded with stars, their visible number increasing a hundred fold after each improvement in the telescope. Through instruments and methods of precision, one of the most helpful of the latter being mathematics, we have learned that each luminous point is a mighty sun, blazing in illimitable distances, its light taking thousands on thousands of years to reach us across the cold, empty, intervening space. We have also found out how far away a few of the nearest are, and of these one can measure the size, even to a million times the substance of our sun. We can furthermore analyze their chemical composition and discover what degree of heat they radiate—some at least thrice that of our sun. We can guess, but probably never find out with certainty, whether living organisms exist on any of the non-luminous planets which may (unknown to us) revolve around them. Nor can we be sure whether our planets or any others have been thrown off from a central orb, or whether, on the contrary, a sun has picked them up in their whirl through space, as the earth picks up meteorites. Nor do we know whether this our solar system is cooling off, running down like a wound-up watch to end in cold stagnation. Nor are we sure that we are not still in progress of heating-up for more cosmic adventures.

The better aided our vision, the more stars we see. Is there any end to the mighty series at the center of which our earth seems to us to stand? Probably, indeed, no other point has a better claim, for infinity has neither center nor circumference. One can not even conceive of an end to space, or a limitation in the number of stars space may contain; nor can we, on the other hand, conceive of its having no limit. All that we know may be included in infinity, yet forming no fraction of it, because a fraction means limitation of the whole. Neither is the problem eased by the unscientific presumption that the universe itself may be a sphere, and that all outward motion, actual or fancied, in its range would be like a line on the earth which, if pushed far enough, returns on itself. An ant travelling over the surface of a globe has been suggested as an illustration of this hypothesis.

A like paradox appears in the case of time: "Time is as long as space is wide." By this declaration Professor Hutton, of Edinburgh, startled the Scottish theologians of the eighteenth century. Space

[1] For an illuminating discussion of this problem, see Dr. Paul R. Heyl, in THE SCIENTIFIC MONTHLY for July, 1924.

had steadily widened on their hands, but they clung to the idea of a wicked and short-lived world, "a sink of iniquity," created not long ago and soon to pass away "in planetary combustion." Hutton, however, saw in its structure "no trace of a beginning: no prospect of an end." As a matter of fact, inspection of the geologic configuration of our globe plainly shows that its hard crust was inconceivably old, hoary with age, before life of any kind appeared on it.

What then of the sequences we call time? What happened one year or a hundred years before time began? What will happen a year or a hundred years after it shall end? How, indeed, could it have beginning or end? That time as well as space means infinity has led some to regard the two as identical. In the assumptions which make up algebra, this may be true. But with our own eyes we can see a tangible bit of time, a sample—not a fraction, for infinity is indivisible—to be quite unlike a sample of space. Ten hours can not be balanced against ten miles.

The point is this: in the majestic whirl of astronomy in which cosmic order seems the one dominant feature, do we get a glimpse of the heart of the infinite? Do we find here the master key which shall tell us "what God is and what man is?"

The students of microphysics, in making their plea, are not less strenuous than the astronomers. "Large" and "small" are relative terms only. Each of us brings what he knows to the measure of a man. But in the almost infinitely (never quite infinitely) small, the phenomena of orderly change on which all scientific conception must be based are just as tangible as suns and planets. The molecule, as we used to describe it, is made of atoms, that which "can not be cut," as the Greek term signifies. But the skilful experimenter now cuts up his atoms into electrons, each atom being conceived as a minute planetary system, with its own central nucleus and its revolving electrons, each with its own acceleration and retardation under influences of heat or electricity. In this view, the expanse of the universe is conceived as "a restless troubled sea," yet a sea in which reigns a majestic cosmic order.

There is a disposition among physicists to regard theirs as an exact science, because its units, as far as we know, are alike and invariable. Accordingly these submit to be counted or measured, and for purposes of science, a thousand electrons are all of the same nature. They have no individuality, and for that matter, except for difference in bulk and station, we find little individuality in planets or stars.

Let us now go beyond the current discussion and search for our master key in biology, the realm of the inconceivably variable. The make-up of animals and plants, to be sure, lies within the range of the science of chemistry, though their essential quality, that of being "going concerns," seems to transcend chemistry. Their substance is subject to physical laws; but they have in addition what planets, molecules and electrons do not possess, functional organization. And in the survey of organization we find an array of marvels, subject to constant variation in time and space, beyond the capacity of suns or electrons, though the activities of life are conditioned by both.

Whether or not there exists an extra-physical or vital force, a matter which (as Dr. Brooks used to say) "we shall never know until we find out," one recognizes certain features of organized life which contrast sharply with those of unorganized matter. With organization, for example, we have *individuality*, no two individuals being actually alike.

We also observe *irritability*—response to external stimulus; *metabolism*—waste and the need of food; *reproduction*—the casting off of matured cells to form new individuals, this including the fact of sex and its varied ramifications; *mortality*, under its phases of growth, maturity and death; and evolution, the capacity to develop new forms through the normal processes of *heredity* and *variation*, and the directive influences of *selection* and *segregation*.

More marvelous than gravity or chemical affinity, and even more elusive still than the visible phenomena of organic existence is the development of the hidden powers in the cells cast off for reproduction. Bound up in the structure of the microscopic chromosomes of the cell-nucleus, in some inscrutable fashion, are the traits of ancestry which tend to make each living being, under similar circumstances, react to life as did its ancestors, the fact of double parentage operating to provoke or insure constant change from generation to generation.

One illustration out of thousands occurs to me as I write. In the warmer parts of the Pacific lives a genus of large, mackerel-like fish, the Oceanic Bonito, called in the South Seas *Aku* or *Atu;* in Japan, *Katsuwo*. These fishes travel about in mighty hordes, one ninety-six miles long having been reported as passing Hawaii. They cast their spawn in the open sea, the egg-cells, minute, transparent, practically invisible, carrying a bit of food-yolk to feed the developing young, the sperm-cells without yolk and therefore ultra-microscopic, but each with rudder-like tail, moving about by the million, yet soon to die in enormous numbers, wasted like the wind-blown pollen of the pine.

Each quiescent egg-cell as well as each wandering sperm-cell carries the hereditary tendencies of his race—to develop a backbone, gills and fins, to take a fish-like form, which in time will assume the mackerel traits of thin scales, teeth, skeleton and all the other details. Development, however, depends upon the union of sperm and egg, without which both speedily die. That union accomplished, the embryo begins to show the special traits of its genus, the chief one being a peculiar interlocking of certain vertebral processes. Later each little fish takes on the special form and the four long, curved, black stripes of its particular species. Lastly, no two individuals, no two germ cells for that matter, being ever exactly alike, a small degree of variation from all its fellows appears in each completed *Aku*.

A similar illustration could be drawn from the life history of any animal or plant, though usually on a smaller numerical scale. Yet the pollen in the pine woods of Michigan, blown by the wind and beaten down by rains, covering ponds with what is called "sulphur," presents the same phenomenon. Each pollen grain and each ovule in the maturing cone dies unless mated. Every pair thus mated bears in its nucleus a composite image of its own kind of pine tree, to be developed at last as a complex of the two.

It was in a living "flower of the crannied wall" that Tennyson sought for the master key. This is perhaps infinitely beyond our reach; but in the organization of living matter we may at least come as near to the understanding we seek as through the sublimity of the universe or through its minutest atoms.

Still another thought arises. No tiniest organism lives to itself alone. In the conjugation of cells in one-celled creatures and in the aggregation of cells by which complex forms have been gradually evolved, we recognize a process of harmonious cooperation which rises in continuous series to the incalculable complexity of the human brain.

In cooperation toward common ends or to meet common needs, even among the lowest animals, we note the stirrings of the abiding principle of altruism. This reaches its height, in humanity, in the love of the family. The broadening and intensification of altruism is as much inherent in the universe as the movement of planets or electrons. Do we then find in love the master key?

Or shall we look still farther? Tyndall somewhere asks the question as to whether he knows all that can be known about the formation of a crystal. That he can not believe. Has anybody already said the last word concerning this relatively simple process? Have we indeed said the last word concerning anything whatever in the universe? Huxley asserts that "nothing endures save the flow of energy and the rational order that pervades it." Can we define—can any one define—this "rational order?" While the imaginations of all races have been busy describing God's attributes, stating those in terms of human experience, is not His essence inscrutable, inconceivable, unknowable? Is He not infinite? Who grasps infinity? Can we coherently try to compass the source of all being, of all energy, of all order? "Canst thou by searching find out God?" On the other hand, can we conceive of His non-existence? In view of all we know or see or feel, can we assume that no rational order lies in it or behind it? Huxley, impatient with conventional orthodoxy and alike with conventional pessimism, says bluntly:

> I am utterly unable to conceive the existence of matter, if there is no mind to feature that existence. . . . The problem of the ultimate cause of existence is one which seems to me hopelessly out of reach of my poor powers. Of all the senseless babble . . . the demonstrations of these philosophers who undertake to tell us all about the nature of God would be the worst, if they were not surpassed by the still greater absurdities of the philosophers who try to prove that there is no God.

It is plain that neither in "systematic theology" nor in science has the last word been said. In astronomy, in physics, in life, in space, in time, in thought, we find ourselves baffled in the face of infinity. The master key which shall open all doors which lead to the Creator no man has yet found. Does not that also lie within the gates of infinity?

THE FISHERIES OF ALASKA[1]

By The Honorable HENRY O'MALLEY
UNITED STATES COMMISSIONER OF FISHERIES

My extended travels throughout Alaska have thoroughly impressed me with the enormous extent of that territory. A map of Alaska placed on a map of the United States would extend from Georgia to Oregon. This is due in part to the long Aleutian chain of islands, but, as the territory contains 580,000 square miles, it is nearly equal to the area of the United States east of the Mississippi River.

When I mention Alaska you probably see visions of ice, snow, polar bears and gold. Little, if any, thought is given to the fisheries. Yet, since the purchase of Alaska from Russia in 1867 for the modest sum of $7,200,000, the territory has produced more in fishery products than in any other resource. The total value of such products, including aquatic furs, since the purchase of Alaska, is about $625,000,000 as against about $517,000,000 for all minerals. The present annual value of the fisheries is about $40,000,000 as against a much smaller sum for minerals.

While the Alaska fisheries include salmon, halibut, cod, herring, shrimp, clams, whales and other products, it is the salmon which gives Alaska its chief commercial product and the world two thirds of its canned salmon.

The story of salmon is one of great interest. As natural history, it is also a story of ruthless destruction of one of the greatest of our natural food assets. It has been a constant struggle between those who look to the next generation and those who seek immediate profit.

[1] Broadcast from Station WRC, Washington, October 29, 1925, under the auspices of the Smithsonian Institution and the direction of Mr. Austin H. Clark.

The salmon, once the pride of the streams of the North Atlantic, have vanished. In twenty-eight rivers between New York and the Canadian border millions of salmon once spawned. To-day only a few thousand survive, and the Penobscot alone receives their visits. A valuable food supply has been completely exterminated on the Atlantic. On the Pacific a similar process is going on, but fortunately time still remains to save there a remnant of the great schools which once swarmed its waters. Many Pacific streams are already depleted. Some can still be saved.

In at least one respect the salmon is unique among living things. Hatched in some quiet lake or stream at the headwaters of a great river, it stays there but a short time and then swims to the sea—where, no man knows. The life of a salmon ranges from two to seven years. The age of an individual is readily determined by observation of the rings on the scales under a microscope in somewhat the same manner that a tree's age is told by a cross-section of its trunk. For some years the salmon stays in undiscovered ocean depths, but never does it forget its birthplace. When its life span is about spent, it returns again to the spot where life started and there spawns and dies. The period of absence varies with different species, but all have this common homing instinct—that where life commenced for them, there it must end, and there their descendants must likewise start life.

This peculiarity has one inevitable result. Since each stream is visited only by the fish hatched in it, when the as-

cending salmon are all once caught and propagation prevented, that stream ceases to be a salmon stream. No other salmon will visit it. It can be restocked only artificially.

There is an unexplainable peculiarity in the salmon runs. They are not uniform from year to year. They show great fluctuations, high years followed by lean ones, in cycles of some regularity. Conclusions as to the condition of any stream must therefore be based upon the consideration of runs for a series of years, deductions from figures for only a few years being wholly unreliable.

Almost the entire commercial catch of salmon is made from the mature schools on their way to the spawning grounds. In districts where streams enter boldly on the outer coast line, the salmon are not seen and are not subject to capture until they school up immediately outside the river's mouth. But in districts like southeastern Alaska, they traverse long salt-water channels on their way to the spawning beds and must run the gauntlet of attack for the entire distance. Unless their migration paths are learned, and a close watch kept on each stream to assure the escapement of an adequate reserve of spawning fish, depletion will surely occur.

In the commercial fishery three chief methods of capture are used—traps, seines and gill nets. Hand lines, wheels and dip nets are used in a minor way.

After removal from the water, the salmon are taken to canneries where they are cleaned by a machine known as the "iron chink," so called from the fact that it has taken the place of many Chinese who formerly cleaned the salmon by hand. The fish are then carefully washed and cut by machine into lengths suitable for the cans. Before the filling machines deposit the salmon in the cans a quarter of an ounce of salt is measured in. Tops are then put on but not tightly sealed. Next, the cans go to the steam boxes for fifteen minutes, where the air is heated and exhausted. Then they are hermetically sealed and sent to retorts, where they are cooked in steam for an hour and a half. After being cooled and labeled they are packed in cases, usually forty-eight to the case. It will be seen that practically all the work of salmon canning is done by machinery and the product is scarcely touched by the human hand.

At this point I wish to call attention to the great food value of canned salmon. There is nearly always considerable waste in meats, while with salmon there is nothing to throw away but the can. Meats spoil quickly in the home, but canned salmon, if unopened, will keep indefinitely. All five species of canned salmon are highly nutritious and when canned differ chiefly in color, firmness of flesh and proportion of fats. The red, or sockeye, and the chinook, or king salmon, command the highest prices, but the coho, or medium red, and the pink, or humpback, are excellent in flavor, though the flesh is paler and not quite as firm as the red or chinook. The chum salmon has a pale or yellowish color when canned. It is the least expensive, but is rich in food values. The Bureau of Fisheries will gladly furnish on request a variety of recipes for preparing canned salmon.

The laws and regulations for the conservation and protection of the fisheries of Alaska are administered by the Department of Commerce through the Bureau of Fisheries. This is a highly important and responsible duty, as it involves control of an industry whose investment runs into many millions of dollars and which gives employment to more than twenty-five thousand persons.

The Yukon River affords an example of the provision which the department makes for the welfare of natives and local residents. Some years ago canneries at the mouth of that river, beyond the jurisdiction of the department under the law then in force, threatened the future of the salmon runs. The natives

suffered hardships, but the department was powerless to act. Under the new law regulations have prohibited commercial operations at the mouth of that stream, with the result that an ample escapement of salmon is assured for the future, and the resident population will not suffer from a lack of salmon due to commercial activities. The law provides for uninterrupted fishing by all residents to provide food for themselves and their dogs, which are so indispensable to winter travel.

In protecting the fisheries of Alaska, an active patrol is carried on throughout the season, which extends from May through September, depending on the locality. As there are 130 salmon canneries in Alaska, located all the way from the southern boundary to Bering Sea, the magnitude of the undertaking can be appreciated.

Preliminary returns indicate that the total pack of salmon in Alaska in 1925 will be about 4,300,000 cases as compared with over 5,200,000 in 1924. This decrease of about 900,000 cases, or approximately 18 per cent., was due largely to the light runs in Bristol Bay and Alaska Peninsula regions. Other factors were involved, including the regulations of the department necessary to rehabilitate depleted runs.

The restoration of salmon runs which have been seriously reduced or even almost eliminated through intensive overfishing is an interesting problem and one in which successful results will undoubtedly follow. It will require a number of years, but eventually, through the regulations of the department, the business will reach the maximum of productivity. When a ton of coal is removed from the ground, there is no way whereby man can replace it, but obviously the restoration of a natural resource like the salmon fishery is possible through intelligent methods of conservation.

The great value of the Alaska salmon is apt to cause one to overlook the other fisheries of the territory. The halibut fishery, chiefly on offshore industry, is protected by an international treaty between the United States and Canada. Halibut taken on the offshore banks are landed in Alaska, British Columbia and Seattle. Large quantities are frozen or packed in loose ice and shipped to eastern markets. In fact about 85 per cent. of the halibut come from banks off Alaska.

The herring industry yields products valued around $2,000,000 annually. While the chief use of herring is for human consumption, large quantities are used for bait in the halibut fishery. In addition, herring, of the smaller sizes less desirable for salting, are used in the manufacture of oil, fish meal and fertilizer. Part of this oil is later used in making edible fats, while the fertilizer is an indirect food producer through enrichment of the soil. The herring fishery, which is chiefly an inshore industry, is far from being developed to its potential capacity. The whaling industry is confined to the waters about the eastern end of the Aleutian Islands, where it is of considerable importance. Last year 283 whales were caught in Alaskan waters. Alaska also yields clams and shrimps of fine quality, and the commercial fishery for both is assuming important proportions.

In conclusion, I want to leave with you one further thought, namely, that Alaska, with its splendid mountains, magnificent glaciers and other natural beauties, all of which are easily and inexpensively reached through the wonderful inside passage of one thousand miles or more from Seattle, has also a further fishery charm for the tourist or casual visitor as well as for the resident. I refer to the angling. The waters abound with trout and other game fishes. And if one is fortunate one may enjoy the thrill of landing a fifty-pound king salmon on a trolling line. Let me urge you to visit Alaska at the first opportunity.

ANIMAL VOICES

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In the discussion of the various noises made by animals the natural tendency has always been to argue from the point of view of a human being in a highly organized society carefully protected from all his enemies. By such an individual any sort of sound can be produced with safety, and sound production has been crystallized by custom into expressions of emotion wholly impossible for the savage tribes living in constant fear of other tribes about them, still more so for the animals.

We recognize, of course, certain fundamental sounds, quite uncontrollable, like screams of pain and howls of anger, but beyond such primitive types of sounds as these it does not seem possible to compare the sounds we make with any of the sounds made by the animals.

No plausible reason so far has been shown for the very diverse voices of the animals. Especially in the case of birds sentiment is commonly supposed to play a leading part. But every living creature is throughout its life so persistently beset by enemies that sentiment as understood by us can scarcely enter into its existence. Male creatures are supposed to sing in order to attract and please the females. But there is little evidence in most cases that females are attracted or are pleased by the songs of males. The male is probably the noisy sex, simply because it does not produce eggs or young and hence has considerable surplus energy available for other purposes.

Let us look more closely into sound production by the animals.

Life on the earth exists in alternating periods of light and darkness of, on the average, the same duration. Besides the difference in the amount of the illumination the day is usually noisier than the night because of the more general motion of the atmosphere. Diurnal creatures are very varied in their coloration and if they live in open places or above the protection of the foliage are often very gaudy in those regions where the light is strong. They are mostly silent, especially the less active and less conspicuous types like the mammals and the reptiles and the numerous crawling insects, bugs, caterpillars, young grasshoppers, etc. Extremely active kinds, like small birds that live exposed in open places or above the foliage, large birds of meadows, strands and marshes, the adults of grasshoppers, cicadas and some butterflies, are often very noisy, while very nearly all diurnal insects make a noise in flight. The songs, chirps or other sounds produced by these are almost always high in pitch and readily perceived.

Nocturnal creatures are much less varied in their coloration than are those that move about by day, mostly dull or mottled, never gaudy, though some nocturnal moths are rather bright. With the setting of the sun the wind dies down and with it the rustling of the leaves and branches so that the night is quiet in comparison with the day. But in contrast to these physical conditions most night-ranging animals are noisy, many extremely so. As examples may be mentioned the foxes, coyotes, wolves and lynxes, jackals, hyenas, lions, tapirs,

bats and many other mammals, at certain times the very numerous kinds of frogs and toads, nocturnal lizards like geckos, nocturnal birds like goatsuckers and owls and very many different kinds of insects, particularly some grasshoppers, katydids, locusts, crickets, and their allies, fulgorids, and some others. While the cries of animals in the daytime are almost always more or less high in pitch the sounds produced by the nocturnal types, though usually less varied for each species, have a much greater range; they may be either high in pitch, sometimes very high like the squeaking of some bats and the stridulations of some insects, or low like the roaring and the bellowing of the larger mammals and of the larger frogs and toads.

Many diurnal creatures when they move give out rustling body sounds like the birds and butterflies, while the corresponding forms of nocturnal habit have various special adaptations which make their flight quite noiseless as in the goatsuckers and owls and in the great majority of moths. These adaptations may or may not be combined with a loud voice.

The nocturnal creatures best protected from attack, such as the armadillos, skunks, porcupines, hedge-hogs, nocturnal snakes, and large and powerful predaceous insects, nearly all are voiceless or practically so.

Among all types of animals brilliancy and boldness of color pattern are chiefly characteristic of the more active, more restless, more exposed and more numerous males, more rarely and only under special conditions characteristic of both sexes. In the same way the possession of a voice, especially of a loud and high-pitched voice, is, generally speaking, confined to males, but under special conditions may be characteristic of both sexes.

Very many of the most vociferous songsters among the birds are brilliant males whose mates are dull in color with merely a high-pitched chirp or all but voiceless, as among the finches, tanagers, orioles and warblers, or to speak more definitely as in the goldfinch, indigo bird, rose-breasted grosbeak, scarlet tanager, baltimore oriole, bobolink and redstart. But very many other songsters are males, brilliant or dull, of the same color as the females, as in the song and other sparrows, most thrushes, larks, wrens and allied types, some orioles, some hummingbirds and various other kinds.

There must be some special meaning in the curious though well-known fact that our gaily colored song birds like the tanagers and orioles after the breeding season change from their brilliant livery to the dull garb of their females and at the same time lose their voices; or more properly with their assumption of the females' habits they adopt the females' voice and dress.

Gregarious birds usually are noisy, like the parrots, shore birds, geese and many ducks. In some gregarious birds, as certain pigeons and such ducks as golden eyes or "whistlers," the noise they make arises wholly from their wings.

No bird is wholly silent. Practically all the smaller birds have a high-pitched chirp and the males at times a song as well; the larger have a varied range of cries. Many in addition to their vocal efforts produce a wide array of sounds in other ways. Such are the woodpeckers, which have the habit of tapping with the bill on any resounding surface; many gallinaceous birds, ground-frequenting finches like the towhee, and some others, and certain other kinds, that make a rustling noise by scratching twigs and dead leaves with the feet; such birds as storks and owls that make a clattering or snapping with the bill; and many birds, particularly some pigeons, ducks and shore birds, with very noisy wings. In a few birds practically the only sounds are made by non-vocal methods.

In the spring with us the arboreal and terrestrial frogs, like the tree and wood frogs and the toads, collect in pools to spawn. At this time they are very noisy. Only the males sing, and the usual idea is that they do this to attract the females. But we have no evidence that the females pay much attention to the song. Collected from wide areas in small pools and puddles, the males could easily find the females without recourse to vocal effort just as do the males of certain turtles, like the sculptured turtle, which, though primarily terrestrial, mate in ponds and streams in spring.

In all the very numerous noise-producing insects the sexes are alike in color, though the song is in by far the larger part confined to, or much louder in, the males. Some insects, like the death-watch, make use of tapping on hard surfaces somewhat as the woodpeckers, while very many, not usually considered "vocal," like some birds have noisy wings.

These, briefly stated, are the facts that we must harmonize in any explanations of the meaning of the sounds made by the animals. The significance of these sounds undoubtedly is varied; but at the same time there must be one major meaning to which all the others are subordinate.

Let us begin our inquiry into the significance of animal sounds with a mention of the simplest and most constant sound in nature, the washing of the sea. Waves breaking on the shore and the white caps on the open ocean give forth a high-pitched hissing sound, consisting of an infinite number of separate sounds arising from the breaking bubbles which rapidly succeed each other.

Prolonged interrupted sound is intensely disagreeable, and soon becomes distressing. We all have noticed this in the prolonged ringing of an electric bell, in the continuous rumbling of an idling motor engine, and in other ways. Being high pitched, the hissing sound of breaking waves has a marked directive quality; it is easy to perceive its point of origin. Being unceasing and interrupted it is distressing and repellent, and all the more sensitive sea creatures try to keep away from it. Whales, porpoises and dolphins and many fishes keep always well off shore, guided apparently by these repellent sounds, while on a windy night various other types of life which normally would come up to the surface stay well beneath it. The simple breaking of the waves is of immense importance to sea creatures as an index of the dangers that they run. In times of storm the repellent sound increases and by this they are warned to keep further from the shore and further down beneath the surface.

The various noise-producing fishes all make monotonous interrupted sounds, usually low in pitch and most deceptive in direction. The few crustaceans that are sound-producing make a continuous clattering or snapping noise.

All these sounds heard beneath the surface of the ocean have the same repellent quality. They may be called "Keep away" sounds because of the natural reaction to them.

Prolonged interrupted noises are very commonly produced by land-living creatures. Perhaps the most typical of such "Keep away" sounds on land are the high-pitched rattle of the rattlesnakes and the loud hissing of the cobras, or the rustling of dry leaves by other snakes or by ground-frequenting birds. The hum of the mosquitoes and the buzz of the wasps and bees and flies are also good examples. If we hear these snakes or insects we instinctively recoil from them, even if we have no idea what they are. The buzzing of a harmless bee-fly in a room is just as distressing as the continued buzzing of a hornet, and the sudden hissing of an unsuspected snapping-turtle in New England will make

you jump as quickly as the hissing of a cobra out in India.

It seems self-evident that such sounds as these are primarily protective in their nature and are admirably adapted to deter an enemy from examining too closely into their point of origin.

Prolonged interrupted sounds are characteristic of all the noise-producing insects, crickets, katydids, grasshoppers, locusts and their allies, cicadas and fulgorids, beetles, moths and butterflies, spiders and centipedes, and of most flying insects, especially the flies and hymenopterous types, the beetles, bugs and others. The details of these insect songs, like the ways in which they make them, vary very greatly, but the general principles are the same in all. Some of the small birds, especially among the sparrows and the tanagers, and certain of the smaller rodents have just the same type of song. The cries of the companies of toads and tree-frogs in the springtime and the incessant cries of many flocking birds probably are deterrent cries of the same nature, at least primarily.

These also seem to be protective sounds developed to deter their enemies. If heard too near all of them to us are disagreeable, and there is no reason to suppose that their effect is different on the animals. Some few things will follow up these sounds and catch the singers, having learned thus to reverse their normal instincts. But such reversal of a normal trait is not by any means unusual and does not affect the general idea. The cannibal fishes of the South American rivers, for example, are strongly attracted by the same hissing sounds which are so very repellent to nearly all other fishes.

In the case of protective coloration each individual must be so garbed as to be at least conspicuous. In the case of protective sound production a part can be of service to the whole except in those conditions, as among the flying insects, where the individuals are emphasized. Thus it is that throughout the animal world songs are mostly peculiar to one sex, the male, which has assumed the duty of this type of protection while the females lay the eggs or rear the young.

Very many of the birds and mammals and some of the amphibians, if they are roughly seized or badly frightened, emit a single high-pitched shriek or a more or less extended series of high-pitched cries. These high-pitched cries of pain and fright have a marked directive character and no repellent quality. They attract immediate attention and at the same time allocate the creature giving them. We recognize at once the similarity of these cries of distress, no matter from what animal they come; but why should they all have this common quality? They are "Come to me" cries wonderfully perfect in their action. Any predaceous creature will recognize such cries and come at once to the spot from which they issue. But any predaceous creature keen in the capture of the animal in obvious distress will in most cases also be an enemy of the aggressor. The former by a high-pitched shriek of pain deliberately calls up an enemy to escape the latter. In the vertebrates these cries are characteristic of both sexes and especially of the young. They occur in a few insects; you can hear the male cicadas give them when they are pursued by cicada wasps.

As an example of how effective such a cry may be, I was recently in a field in Essex, Massachusetts, when I heard a constant squeaking in the grass. It was easy to determine its exact point of origin. There lay a small black snake with a young meadow mouse (*Microtus*) in its jaws. The snake made off at once holding the meadow mouse, caught firmly by its side, high in the air; but soon it dropped the mouse and both

snake and mouse scurried to safety. By its loud persistent squeaks the mouse had led me to the place where it was in trouble. The snake on seeing me approach too near let the little mouse go free.

The smaller birds commonly make use of this "Come to me" type of cry to frighten intruders from their nests. Thus the common robins give forth loud and piercing cries with the certainty of attracting to the spot any prowling hawk or owl or other enemy of the nest robber which itself will not disturb the nest and which they can escape by dodging through the branches. The "Come to me" cries of robins are nothing but invitations to their enemies which are thus called in expectation that they are equally the enemies of the prowling thief.

In this connection it is interesting that badly wounded birds or mammals seldom make a sound; they try to hide or to be as inconspicuous as they can. If seized, however, or badly frightened by a near approach, they commonly give vent to cries, and sometimes under these conditions birds will sing.

Most small birds, especially the very active ones like the finches and the warblers, from time to time emit a sharp and sudden chirp, whistle or other sound of a similar nature. This locates them at once to all the animals in hearing distance. But they are always on the move. No sooner do they chirp than they go on to another place. Thus they continually call attention to the places they have left and the chirp is never sufficiently prolonged to indicate what direction they have taken. Because of their superior activity and their power of flight these "Here I am" cries are especially characteristic of the birds, particularly of the smaller birds, but many active mammals have them also, like the tapirs, forest dogs and certain of the monkeys in South America, and various small rodents and other mammals elsewhere. They are rare among the insects, but some have them, like "whip-cracker" butterflies (*Amphichlora*). Many birds give these cries when they are on the wing, especially at night; you hear them from the warblers on migration and just before the rises of the strongly undulating flight of goldfinches and of some other birds.

This type of cry is easily reduplicated, varied and expanded into a more or less prolonged and complicated song, and in the birds, indeed, all possible intergrades occur between a single chirp and a perfect and continuous song. But if bird songs are in reality a development from the isolated single chirps of little birds they must necessarily in some way carry out in a more extended form the original significance of those chirps from which they had their origin.

Our attention is at once attracted by the songs of birds, and few people are so callous that they will not glance in the direction of a performing songster, which is almost always easily determined. We have no enmity toward the little birds; they please us with their songs and they destroy the insects that attack our crops. We therefore look on almost all of them with tender sentiment. But let me repeat that every creature in the world is so beset by enemies that it leads the most precarious sort of an existence. Any false step means its death. Any transgression of the rigid limitations within which life for it is possible, whether by individual variation in form or structure or by unfortunate accident, means the prompt elimination of the individual so transgressing. It is inconceivable, therefore, especially in view of the common qualities of all bird songs, that the voices of the singing birds should not be a part of that delicate adjustment which we

recognize in form and structure and in color. Animals that seek their prey by day, except the majority of the parasitic and predaceous insects and some mammals which are guided largely by their sense of smell, chiefly depend on sight; particularly are they quick to detect motion. Diurnal animals therefore are wonderfully varied in their coloring, each type of color being especially adapted best to conceal its wearer from his enemies in his normal habitat when acting in his normal way. But many predaceous things that hunt by day are guided by the ear as well as by the eye. Is it not quite as necessary, therefore, that their intended victims should be able to deceive one organ as the other?

Among the song birds there is little evidence in most cases that the females pay much attention to the songs of males, though it is probable that they serve to some extent, in the cooing of the doves, for instance, or the creaking of the grackles, as a sex stimulus. The male is the aggressive sex, and the males therefore occupy positions where they can best watch out for females. In such positions, in a tree top, on a bare twig or a branch end, on an exposed rock or hovering in the air, they are especially subject to attack by all their winged enemies. Their coloration at the mating season, often very bright in startling contrasts and widely different from the somber females, is especially adapted to conceal them when they are on the lookout for their mates. The movements of small birds are very quick and discontinuous, lightning-like action alternating with almost rigid immobility; this adds to the effectiveness of their concealing coloration in giving a constant change of background so quickly made as to be difficult of detection.

The song birds commonly so called all have high-pitched voices; but the songs, unless a disagreeable buzz or trill or rattle, or otherwise similar to the "Keep away" cries of insects, is always modulated and composed of varying notes of different pitch and quality. Sometimes in searching for a songster in a tree top or in trying to locate a skylark or a longspur in the air we have some difficulty in determining his exact position. Yet from the ground he usually stands out against the sky or the blurred outlines of the distant vegetation, and we get his notes in their unaltered values. The song in other words proclaims his presence, but does not reveal so clearly as it might his exact location.

But birds when singing have no fear whatever of ground-living things. It is the hawks especially that are their enemies. A hawk on the lookout for small birds cruises about in an erratic course at the rate, say, of about thirty miles an hour. We all have noticed how much higher is the pitch of the whistle of an approaching than of a retreating locomotive, and the average train does not travel with the speed of a cruising hawk. It is therefore evident that to a hawk the same bird cry will have an infinity of different values between two wide extremes. This would confuse us hopelessly, but the hawks undoubtedly discount this effect. If the hawks have trained themselves not to be deceived by the variations in the pitch of animal cries and in the calls of birds resulting from the speed with which they fly, as it is quite logical to assume they have, we at once see a simple explanation for the songs of birds. A varied song composed of notes of different pitch would be most hopelessly confusing to a hawk. The high notes would indicate to him that he was flying toward his intended victim, the low that he was flying from it. In other words a varied song would most effectively conceal the whereabouts of the singer from any creature passing

rapidly through the air. The songs of male birds in the mating season therefore seem to be nothing more nor less than a development of their normal calls into a medley of sounds most admirably adapted to conceal their true location from their enemies that fly and hunt by ear, just as the special colors most of them assume are especially adapted to conceal them from their enemies that fly and hunt by sight. By the development of songs and special plumage in the mating season male birds are enabled to occupy exposed positions and thence watch for the females which otherwise they could not do.

The same "Where am I?" quality is characteristic of the noise produced by many of the larger birds in the courting season, though these make use of most deceptive low-pitched sounds, and in their vocal efforts a sexual significance is much more evident. Good illustrations are the booming of the bitterns and the drumming of the ruffed grouse. The cries of certain of the larger frogs and toads are much the same in nature. This type of cry among the mammals is exemplified by grunts and growls given mostly when alarmed and usually by both sexes equally. I once disturbed a Barbary ape which was feeding on the ground under a fruit tree. The fierce resulting growls seemed to be given out from a whole troop of monkeys all about me, though only one dashed off through the undergrowth.

Whereas by day all creatures are protected from their enemies by very varying types of coloration, this protection largely fails at night, for nocturnal creatures hunt chiefly by sound instead of sight. For such of them as have their eyes especially adapted for nocturnal vision, like owls and lemurs, day-time colors are of course largely ineffective because of the change in color values.

To counterbalance loss of protection afforded by the possibilities of varied coloration nocturnal creatures, especially the insects, have developed to the maximum the protective and other possibilities of sounds.

The period of greatest danger for all creatures is the twilight when altered color values have destroyed the significance of protective coloration, diurnal animals have not as yet composed themselves for sleep, nocturnal animals are awakening, and both diurnal and nocturnal predators are active. All animals need protection most at twilight, and for this reason this is by far the noisiest time of day or night. The singing of diurnal birds at evening and again at dawn is nothing more nor less than a measure of the special dangers that they run at that particular time. Like blinded birds they are doing what they can to ward off unknown dangers. Midday, when protective coloration has its greatest value, and midnight on dark nights are the safest times for all living creatures, and at these times animal sounds are least in evidence.

Especially characteristic of nocturnal creatures are "Keep away" cries of all sorts and descriptions, emanating chiefly from an infinite variety of insects and from small frogs and toads. In addition to the insect types vocal by day are various others, like fulgorids and numerous large slow-flying droning beetles, and some noisy moths like hawk-moths.

"Here I am" noises are not common among night-ranging creatures, and are mostly confined to very active mammals, such as mice, forest dogs, foxes, bats, tapirs and small nocturnal monkeys, and to some of the smaller frogs.

"Come here" cries are often heard at night emanating from the same creatures that would give them in the day-time under similar circumstances.

The "Where am I?" type of cry is quite common in the night, and is especially favored by nocturnal birds, like goatsuckers and the smaller owls, and by those diurnal birds that sing at night, and in a different form by large frogs and toads and by certain large male mammals. Among nocturnal predators, like the large owls and carnivores, this passes into another sort of cry, the "I'm after you" exemplified by hoots, roars and growls coming seemingly from nowhere and presumably effective in disconcerting other creatures and so terrorizing them as to throw them off their guard. Some large owls combine these two types of cries, giving a mixture of high-pitched shrieks and low-pitched hoots as they fly about. Some active predaceous mammals do the same.

As at night the wind usually dies down and the protection afforded by the rustling of the leaves and branches against the detection of similar sounds of animal origin is dissipated. Such sounds are more especially the ordinary sounds of flight among the birds and insects. Therefore, most of the night-ranging birds and some of the night-ranging insects, especially the moths, have developed an almost noiseless flight both to escape detection and to facilitate the capture of their prey.

Special conditions of existence call forth special types of sound production. Those animals that live by day in dimly lighted places act as regards sound like animals in twilight. Open fields in the late summer, when the grass has ceased its earlier luxuriant growth and the blades are withering, no longer shield from sight the grasshoppers, now fully grown, as they did before. To compensate for this loss of protection from the vision of their enemies they develop voices of the "Keep away" type in an endeavor to counteract lack of concealment by deterrent noise.

Summary

Like the various colors with which they are adorned, the similarly varied voices of the mammals, birds and reptiles, amphibians and fishes, and the insects are primarily protective in their nature. By their colors they deceive the eyes of enemies; by the sounds they make they deceive or irritate their ears.

While color is individual and each creature therefore must assume a livery best suited to its particular environment, this is not so in the case of sound production. Here a portion of the individuals can protect the whole. Thus sound production is chiefly a function of the males, correlated with the females' duties of producing eggs or rearing young. But whenever any forms of animal life are individualized, as in the case of bats, birds or insects on the wing, both sexes become noise producing equally.

The sounds produced by animals, sometimes with the aid of inert objects such as dry leaves or the dead trunks of trees, are of several different types.

The majority of animal sounds, especially among the insects and the lower vertebrates, are high-pitched prolonged interrupted sounds which are extremely disagreeable and are designed to deter an enemy from a close approach. These may be called "Keep away" sounds.

Uninterrupted high-pitched cries or shrieks have a directive character without any deterrent quality. They attract an enemy at once. They are especially characteristic of animals in pain or trouble and are designed to bring an enemy in the expectation that the enemy will also be an enemy of the attacking creature. These may be called "Come to me" cries.

Somewhat similar are the "Here I am" cries of little birds and other very active creatures always on the move. These cries call attention to the place

where they were given but which the bird has left.

The isolated chirps of birds grade into the complicated songs of the males of song birds. These are hunted by the hawks flying rapidly through the air. To a hawk in rapid motion the same sound will appear of widely different pitch according to the hawk's course in relation to the point of origin. A small bird's varied song would to a hawk suggest a single sound before, behind and all around it, thus serving to conceal the small bird's true location. The songs of birds are simply "Where am I?" sounds produced for the deception of their enemies at the times when they are most subject to attack. Many of the larger birds produce the same effect by sounds of a low pitch, as do various mammals and some of the amphibians.

Among nocturnal predators "Where am I?" sounds tend to become expanded into "I'm after you" cries—hoots, roars and growls—designed to terrorize their intended victims into a lack of their customary caution.

In addition to the primary function of the voices of the animals as explained above it is clearly evident that animal sounds have come to have several minor, though important, functions. For instance, they are evidently used as a sex stimulus, especially among the birds and the amphibians and in some groups of insects where they seem largely to replace the odors in the mammals and in certain insects, as the Lepidoptera. They are also of importance in keeping flocks and families together, especially among the birds, and in various other ways.

RADIO TALKS ON SCIENCE

THE EFFECT OF FORM ON MATTER[1]

By Dr. CHARLES E. MUNROE
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IT is fascinating to watch the creation of a structure through the laying of brick on brick, or stone on stone, until, by gradual accretion, the structure assumes the form and dimensions sought, together with the symmetry and proportions which bring joy to the eye of the beholder, developed in it through the manner in which the units from which it is constructed have been placed. I have followed with pleasure the growth of many of the fine structures in Washington, among them several of its bridges, the Union Station, and the Lincoln Memorial. I have envied those engaged in the creation of these splendid productions of man and realized how properly proud each man who participated in any way in these achievements must feel whenever he views them.

It is also interesting to watch the demolition of buildings, to observe the bricks and stones being separated from one another and to see that, little by little, the interior is disclosed, ultimately to the foundation, so that the kinds of materials which had gone into the structure, together with the manner of their arrangement and services, stand revealed.

These two operations, constructing a building and wrecking a building, are examples of two processes widely made use of in the study of matter. In the wrecking of a building, by taking it apart, one conducts an analysis. In erecting a building, by putting together its component parts, one conducts a synthesis. Chemists largely employ analysis and synthesis in their studies of matter.

Given, for instance, common salt, which lends savor to our food, or sugar, which sweetens it, or a snowflake caught on a well-cooled coat sleeve, before proceeding to take them apart, that is, to analyze them, the chemist would closely view them, using a microscope by which the minute particles would appear so enlarged that their shapes and appearances would be readily discerned, and he would find each to possess a definite and attractive form, but that each form was quite unlike that of the others. He would pronounce them crystalline in structure. When given freedom of motion, the particles of each tend to produce these definite crystalline forms, and these forms are so characteristic for each substance they serve as means for the identification of the substance. The salt and the sugar were crystallized from solutions in water. The frozen water crystallized out from solution in air to fall as snow.

There are a multitude of crystalline substances to be found in nature. The diamond, ruby, sapphire, emerald; ores of iron, copper, silver, lead and other metals; and substances like graphite, gypsum and calcite may be prominently mentioned. Visit any mineral collection, such as that in the National Museum,

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and Science Service and the direction of W. E. Tisdale.

and you will be charmed by the infinite variety and beauty of the crystals to be seen there and convinced that each substance has a figure all its own.

Having a collection of minerals of your own to choose from, if you were to select a specimen of lead sulphide, such as is used in many radio sets, and which is known as galena, you would find it to be a cube in shape and that, if you crushed it by a blow, the smaller particles also have this cubical shape. Likewise, if you were to select a piece of calcite, which may be styled crystallized marble, and crush it, you would find its characteristic form to appear in its fragments. The characteristic crystalline form of a substance persists quite to the limit of our vision, even aided by powerful microscopes. By the use of X-rays we have learned that crystalline form exists quite beyond that limit.

It is possible that while examining your crystal of calcite or Iceland spar, as it is also called, you put the transparent, colorless, glass-like crystal on a piece of paper which had a spot on it and noted, to your surprise, that you saw two spots where you knew only one to be. Perhaps, in your amazement, you turned the crystal about as it rested on the paper and were further surprised to see one spot rotate about the other. You were not deceived. It is a property of Iceland spar, because of its form and structure, to make you see double. Iceland spar consists of doubly refracting crystals.

Light, as you are no doubt aware, consists of waves oscillating up and down in many planes within a beam of light. Iceland spar, as noted, splits the beam. Nicol conceived the idea of so cutting and rejoining a piece of Iceland spar that but one portion of this light could pass entirely through the reunited crystal, and in the ray that passes all the waves vibrate in the same plane. Such light is called polarized light and the crystals, cut and arranged as devised by Nicol, are called Nicol prisms. With polarized light great marvels may be wrought.

Thus if we put one Nicol prism below the stage of a microscope and another above, at the eyepiece of the instrument, and allow light to enter the lower one, no light will pass through the upper prism—there will be absolute darkness—until the upper prism is brought into a nearly identical position, as regards rotation about the vertical axis, with the lower prism. Biot found there are many chemical substances which, either in the crystalline form or in solution, will rotate a beam of polarized light which is passing through them, and such substances are therefore called optically active bodies. Place an optically active body between Nicol prisms so "crossed" that there is total darkness at the eyepiece, and at once light appears; usually accompanied by most exquisite colors; so that, what with crystalline form and color, optically active bodies, viewed by polarized light, present some of the most lovely aspects man is permitted to view. Among the optically active substances is cane sugar, whose quality and purity are, because of this characteristic, ascertained by the polariscope—an instrument so constructed that a tube containing a prepared solution of the sugar may be placed between its Nicol prisms and viewed by polarized light. To-day large loans are placed on sugar crops and millions in duties are levied according to the results of the polariscopic measurements of sugar.

Wine-making is one of the oldest arts known to man. It is based on fermentation, which rivals in efficiency in changing matter the agent which transforms energy to produce light in the firefly, glow-worm and the animalculae, through which the waters of the ocean compete

with the aurora of the Arctic heavens. It may well be that fermentation and phosphorescence in living beings are due to the action of similar agents. The chemist early turned his attention to wine-making, and though undoubtedly much remains unknown to-day about this marvelous work of nature still much has been discovered.

In 1789, Scheele showed that tartaric acid could be obtained from argols, or the lees of wine, thus creating a new and important industry, for ever since cream of tartar, used extensively in "raising bread," and for other purposes in domestic life, has been obtained from the deposits of fermented grape juice. In 1822, Kestner discovered that the wine deposits yielded racemic acid also, which Gay-Lussac found, by analysis, is composed of precisely the same amounts of the same kind of elements as tartaric acid, yet the two are unlike in properties for, as shown by Biot, while tartaric acid is optically active and rotates polarized light, racemic acid does not rotate it at all.

This was the state of knowledge on these acids when Pasteur, in 1848, began a five years' study on them, eventually proving that racemic acid is composed of two different forms of tartaric acid, both of which are optically active, one however rotating the beam of polarized light to the right (and styled dextro-rotary), the other turning the beam to the left (and called laevo-rotary), and that they existed in racemic acid in equal proportions, so that they neutralized each other's effort to turn the beam of polarized light.

During this investigation Pasteur devised ingenious means for crystallizing out a salt of racemic acid by which he obtained small crystals alike in all respects, except that on one half of the crystals the ends were provided with a set of facets which were arranged about them in right-hand order, while on the other half similar facets were arranged in left-hand order. When, by the aid of a magnifying glass and forceps, he separated these he was able to produce three solutions: (1) of the original mixture of crystals; (2) of crystals having facets arranged to the right; and, (3) crystals having facets arranged to the left. On polarizing them, (1) was found to be inactive, (2) rotated the beam to the right, and (3) rotated the beam an equal extent to the left. More remarkable yet, Pasteur found that an organism, such as *Pencillium glaucum*, growing in a racemic acid solution, would devour the dextro-tartaric acid, and leave the laevo-tartaric acid untouched. Since then many other instances of racemation have been discovered among organic compounds and special micro-organisms that selectively feed upon one of the isomers, as such similar compounds as the tartaric acids are called.

Pasteur then passed on to the further study of fermentation, as exhibited in the making of bread and the brewing of beer, and, with the knowledge thus gained and the technique thus acquired, to the study of contagious diseases in the silkworm, animals and man with the result that he conquered virulent diseases like anthrax and hydrophobia; revolutionized the art of surgery and the practice of medicine; saved much suffering, extended life; and improved the conditions of living.

Some twenty years after the discovery of racemation by Pasteur, van't Hoff and Le Bel accounted for the optical behavior of the tartaric acids by the internal arrangement of the atoms in their molecules, and continued research has shown that the properties of matter are dependent not only on the kind of materials which go into the construction of their molecules but also the manner in which they are arranged.

THE AGE OF SYNTHESIS

By H. E. HOWE
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THE possibility of referring to "synthetics" in the title of a radio talk indicates the increasing number among the public that have become sufficiently interested in modern science to form at least a nodding acquaintance with it. At any rate a number of synthetic articles with which the public is familiar might be mentioned, but none of these are quite so beneficial as those to which reference will be made.

The world has consumed more metal in the last twenty years than in all the preceding twenty centuries. We use wood four times as fast as it is being grown, and certainly our coal and petroleum resources are being drawn upon at a rate far exceeding their replacement, if indeed they are being replaced anywhere on the earth. These and similar facts bring home to us the seriousness of the question, How long will the earth be able to maintain its population at anything like the present high level of civilization? Will the limiting factor be rainfall, upon which the production of food depends? Will it be the success which may attend our efforts to overcome the molds, yeasts, bacteria and insects which threaten our food supplies? Or will it be the extent to which the scientists are able to discover supplementary resources or synthesized materials to replace those consumed by an advancing civilization?

The scientist looks with considerable confidence to the future because of what has been accomplished and what he believes can be accomplished in future as the sum total of human knowledge increases. The scientist began his work long ago by first determining the constituents of the materials found on the earth's crust and in the atmosphere. He has since applied this information obtained by difficult analysis in stimulating productivity, as, for example, in the application of his data in the field of agricultural chemistry. There, certainly, increased production has followed the application of scientific principles discovered largely in the chemical laboratory. But the replacement of natural resources involves more than a stimulation of production. Many of our most important resources are not produced by annual crops and require a treatment quite different from that serving in some agricultural fields.

What is taking place in the use of petroleum serves well as an example of true conservation through efficient use. The multiplicity of internal combustion motors has made gasoline—once a nuisance to the refiner—the product he most greatly desires. Early in the history of petroleum refining the gasoline that could be obtained by simple distillation was all that was produced. This was seldom more than 10 or 15 per cent. of the oil distilled. Later the chemist showed how to recover the gasoline present in some types of natural gas and also that in the so-called casinghead gas which comes from petroleum wells. These two sources now account for more than nine hundred million gallons of gasoline annually. It was soon seen, however, that additional quantities of gasoline must be produced. The application of the principles of physical chemistry and of engineering has given us a series of cracking processes, so that today more than 60 per cent. of the petroleum subjected to the process is recovered as gasoline, while kerosene and other standard fractions of the oil may also be converted into satisfactory gaso-

line. Even higher conversion percentages may be expected in future.

By synthesis is meant the production of a material by scientific methods to reproduce or take the place of some compound found in nature. Within the present century and indeed within the present decade, many things have been successfully built up by man-devised methods, first in the laboratory, then in a pilot plant and now on a commercial tonnage basis. A few examples will suffice to illustrate why the chemist looks forward to a synthetic age.

At the present time a synthetic hard fat is produced from vegetable oils at an annual rate equivalent to the fat obtainable from seven million hogs. In addition many million pounds of oil are treated by the same process for technical purposes and for use in admixture with the synthetic hard fat. The process consists of adding the requisite number of hydrogen atoms to the liquid fat or oil molecule, whereupon it becomes a hard fat, taking the place of hard animal fats for many purposes. Simply stated, the process consists of treating the warmed oil with the gas hydrogen in the presence of finely divided nickel which takes no part in the process other than to promote the union of the oil molecules with the hydrogen. So long as America can produce such vegetable oils as cottonseed and peanut, it would be impossible to embarrass her by a fat shortage, while the value added to many grades of oil for manufacturing purposes, such as soap-making, has been so enhanced as to constitute an important economic item.

In 1898 Sir William Crookes predicted a famine because he foresaw the exhaustion of nitrates obtained at that time only from the saltpeter beds of Chile. Sixteen years later the World War was begun, the aggressor having perfected a synthetic process for the production of nitrates from the nitrogen of the air. Although first applied as a war measure, the synthesis of ammonia is of greater peace-time importance, since nitrogen is essential to food production and the vast quantities of nitrogen in the air must be fixed in some soluble form to make it available as plant food. Synthetic ammonia is the first step in a series of chemical processes producing a variety of forms of nitrates for plant food. Though this work was begun abroad, America is in position to take a place in the front rank of this work, due to the successful investigations at the Fixed Nitrogen Research Laboratory of the Department of Agriculture and the cooperation of many industrial chemists.

Until recently acetic acid, better known as the acid in vinegar, was made principally by the distillation of hard wood. Calcium acetate was the form in which it was recovered, and from this acetic acid could be produced. To-day this acid is being made in commercial quantities from acetylene, which in turn is made from carbide, and this is the result of a chemical reaction involving limestone and coal.

Another important synthetic material is methanol, formerly known as wood alcohol and until recently derived solely from hardwood distillation. Methanol is an important solvent and is also used as a chemical reagent in the manufacture of such substances as dyes. In its synthesis two gases, carbon monoxide, derived from coal, and hydrogen are employed. The process is similar to that used for the fixation of nitrogen, and costs are reported to be so low as to give the synthetic product a marked advantage over the natural product. Butyl alcohol, a solvent raised to great importance by the development of modern nitrocellulose lacquers such as are now being used on many automobiles, pieces of furniture and even buildings, is still produced principally by the fermentation of corn, but abroad it is made syn-

thetically, and even ethyl alcohol, better known as grain alcohol, is reported to have been synthesized in the laboratory, though not yet produced in commercial quantities.

Most of the examples that have just been cited depend for their synthesis upon catalysts which, though but lately recognized as such in industry, play a vital rôle in most synthetic processes. A catalyst is a substance which, though often used in minute quantities, promotes reactions between other substances at a rate to make them commercial. The catalyst does not appear in the final product, is not itself changed and the exact mechanism of its action is still a question for discussion. It has been described as a chemical parson which unites two elements to form a new group without becoming a part of that group.

Other materials of importance have been synthesized to the great advantage of medicine and surgery. Certain glands, such as the adrenal and thyroid, have been processed for the sake of extracts of great potency. This involved handling enormous quantities of material, the glands of thirty thousand sheep being required to produce one pound of adrenalin. The necessary purification and concentration involves a number of operations which make possible a product more variable in characteristics than is desirable, and expense is always greater where large quantities of raw material must be treated with low yields. This incidentally is one of the reasons why radium is so expensive. The active principles of the adrenal and thyroid glands are now made synthetically, the product being uniform and the prices lower than was possible by the old method. Insulin is another glandular product of which we have heard much in the last few years. Insulin as a pharmaceutical product is passing through the several stages of development and it may be expected that eventually it also will be synthesized.

The flavoring extract manufacturer tells us that vanilla is the most popular flavor in America. Originally made by extraction from Mexican vanilla beans, using alcohol as a solvent, the active principle of this flavor is now prepared from coal tar. It would require the resources of fifty Mexicos to meet the demand for vanilla beans, and without the synthetic product we should be compelled to choose some other flavor or pay an almost prohibitive price.

Lacking such natural resources as we possess in petroleum, the chemists of Europe are striving to synthesize liquid fuels from solid ones. One investigator by treating powdered coal with hydrogen under pressure and at high temperatures has succeeded in an experimental way in converting much of the solid fuel into a liquid one. By using the coal to produce carbon monoxide gas, a synthetic oily liquid has been produced in another laboratory and is looked upon with some favor as a possible supplementary fuel for internal combustion motors.

A synthetic product that is now in great favor is rayon, the man-made silk which not only threatens to become the ultimate successor of natural silk but may ultimately be produced so cheaply as to dethrone King Cotton. Even now the raw materials for a pound of rayon cost little if any more than a pound of raw cotton. When our research laboratories solve the riddle of the constitution of the cellulose molecule—cellulose being the material which makes up wood and cotton, the starting point in rayon manufacture—great improvements may be expected not only in rayon but in many other cellulose products.

It seems unnecessary to remind you that the synthetic products of chemistry most widely advertised and perhaps best known are the synthetic dyestuffs now

obtainable in thousands of colors and shades. Such materials not only have been more satisfactory than most of the animal, vegetable and mineral coloring matters, but afford a range of shade and a fastness of color to light and washing in no wise approached by the natural products.

We smile when we think of the apprehension with which the early English regarded the exhaustion of the yew from which long bows were made for their army. Generations later other Englishmen worried over the shortage of oak for ships' knees, without which the navy could not be maintained. Still later the foremost question in national defense was how to make satisfactory iron without adequate supplies of charcoal, which was growing scarce. In every case, before the expected calamity fell new developments had removed the danger. Thus far science has been able to avert dangers which threatened through the exhaustion of particular natural resources. This does not mean that science invites America to continue to be a spendthrift. Science puts off the time when exhaustion of resources will be upon us by developing better ways of utilizing materials at hand. With the growth of our knowledge of the constitution of the molecule and of the atom of which it is composed, there may come an age of synthesis which will rival in richness and splendor all those which have preceded it.

THE ISOLATION OF ANCIENT AMERICA AS INDICATED BY ITS AGRICULTURE AND LANGUAGES

By Dr. W. E. SAFFORD
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WHEN Columbus and the explorers and colonists who followed him reached America they found that the native Indians, both north and south of the Equator, had developed an agriculture quite distinct from that of any country in the Old World.

In the West Indies they found fields of sweet potatoes and extensive plantations of mandioca, the plant from which cassava and tapioca are derived, growing in long rows and spaced at equal intervals, which called forth expressions of admiration in the reports sent home to Spain. Other cultivated crops were a cereal which at first they compared to millet, with large grains closely packed round a central cob. This was our Indian corn, called *mahiz* or *maize* by the islanders. Other important crops were red peppers, which the islanders called *ahí*, and peanuts, which they called *maní;* and among the fruits was the delicious pineapple, which had been developed by selection from a wild plant with linear bayonet-like leaves armed with marginal spines. Among their potherbs was a plant with enormous leaves, related to our Jack-in-the-pulpit, which in the British West Indies is now called Carib cabbage.

Other important plants of the West Indian Islands were cotton, quite distinct from that of the Old World, and tobacco, a plant unlike anything before seen. In their reports the Spaniards said they "fumigated themselves" with its leaves. This tobacco had undoubtedly been brought, like the sweet potatoes, the cassava plant, the maize, red

pepper, pineapple and Carib cabbage, from the mainland of northern South America, where these crops were also found in cultivation.

The conquistadores who invaded Mexico found the principal food staples of that country to be Indian corn, squashes and beans quite distinct from the well-known *faba*, or bean of Europe. They also found beautiful plantations of the native magueys, or century plants, which the Mexicans had brought into cultivation for the sake of their sugary sap, fermented by them into an intoxicating drink, and that they had improved certain varieties of native prickly pears by cultivation, the fruit of which was so sweet and juicy, although filled with small seeds, that it was introduced into Europe under the name of Indian fig. Another closely allied cactus was the host plant for breeding a certain insect which yielded not silk, like the moths of the Orient, but a beautiful red dye which the Aztecs called cactus blood. This was cochineal, a scale insect allied to that of the Old World yielding the rich crimson with which the curtains of the Ark of the Covenant were dyed.

Perhaps the most important of all the cultivated Mexican plants was the cacao, from which the Aztecs made their chocolate. In certain localities its seeds were used and still are used as money. For flavoring their *chocolatl*, or chocolate, they used the pods of a climbing orchid, which they planted in shaded groves and trained upon the trunks of trees. This was the vanilla, one of our most delightful heritages from ancient Mexico.

In certain localities inhabited by more primitive tribes, sheltered ravines were encountered across which transverse walls of stones had been piled at intervals to retain the soil washed from the plateau above. Each of the terraces thus formed was planted in corn, beans and squashes, and cultivated in a primitive fashion. In Peru were found mountain slopes with miles of irrigated terraces, of which the small ravine dams above described were the prototype. On these terraces and on the coast most of the plants already mentioned were also found in cultivation. The food products of the Peruvian gardens and plantations and imitations of them in the form of pottery funeral vases were interred with their dead. Thousands of specimens of the latter are now to be found in archeological museums of this country and of Europe.[1]

The early colonists of North America found the entire Atlantic coast, from Florida to Canada, inhabited by tribes of Indians who practised agriculture. Their principal crops also were Indian corn, beans, squashes, pumpkins and tobacco. Their tobacco, a yellow-flowered species with stalked leaves, was identical with the *Nicotiana rustica* of the Mexicans and quite distinct from the milder, pink-flowered *Nicotiana tabacum* of the West Indies. The interior valleys of the Mississippi and its tributaries were planted with fields of Indian corn about which twined beans of various kinds and through which trailed the vines of pumpkins and squashes. The Indians cultivated sunflowers, for the sake of their rich, oily seeds, and their relative, the Jerusalem artichoke, for its edible tubers. Farther to the westward were tribes which also practised agriculture, including other species of tobacco and in the arid southwest surrounding the pueblos of the Zuñi and Hopi Indians as well as in canyons bordered by cliff dwellings were cultivated patches of corn, beans, squashes and in some places cotton, all of which were probably intrusions from Mexico.

In the agriculture of ancient North America tropical plants requiring more than a year to mature could not possibly

[1] See Safford, W. E., "Food Plants and Textiles of Ancient America," in *Proc. Nineteenth Congr. Americanists*, 12–30, 1917.

become established. All the crops were annuals sensitive to frost, and had to be replanted each year. On account of the severe winters, the tropical fruit trees found in the West Indies and grown in the warm barrancas of Mexico were absent from the fields and villages of our own Indians.

In a previous radio talk[2] I called attention to the fact that the cultivated plants I have enumerated were all developed from wild American plants, long before the time of Columbus: Indian corn from a grass allied to the Mexican *teosinte*, sweet potatoes from a fleshy-rooted morning-glory, beans from twining plants growing in thickets, pumpkins and squashes from trailing gourds, probably bitter and uninviting in their wild state, and the so-called Irish potato from a wild tuber-bearing nightshade of the Andes of Western South America. Not a single cultivated food plant of the Old World had found its way to America—not a grain of wheat or of oats, rye, barley or rice; not a single fruit known in Europe, Asia or Africa.

In ancient Europe the condition was very different. In the gardens and fields of England, as well as on the continent, were many flowers, fruits, vegetables and cereals, which had originally been brought from distant countries; among them oranges (still called *Apfelsinen*, or Chinese apples, by the Germans), lemons, peaches, quinces, pomegranates, melons, cucumbers, watermelons, which had been successfully introduced into cultivation where conditions of climate and soil permitted; and in Egypt an edible arum, the *kulkas*, or Colocasia, identical with the taro of the Polynesians, and seedless Musa, identical with the banana of southern Asia. The histories of some of these plants are lost in antiquity, but the origin of others can be definitely traced. In addition to plants successfully propagated were certain dried products, such as spices, brought from the distant Spice Islands, some of them worth their weight in gold. It was in quest of these that Columbus set out on his eventful voyage. The presence of these exotic plants and plant products in the gardens and markets of Europe was a tangible proof of communication with remote countries at a very early date.

The most celebrated book on the products of distant lands published before the discovery of America was that of Marco Polo, which described many of these imported plants as he had encountered them in their original home. He was the first to give a detailed description of the coconut palm and its fruit, which he called *nux indica*, or Indian nut.

This valuable palm had been spread by human agency in prehistoric times eastward throughout the islands of the tropical Pacific and southwestward to Madagascar.

In the Pacific Ocean the first European navigators found the islanders subsisting principally on well-known cultivated plants of Asiatic origin. Possibly some of you who are listening to-night do not realize the vast area covered by the islands of Polynesia, a great triangle with sides two thousand miles long, with the Hawaiian Islands, New Zealand and Easter Island for its three points, the last, a tiny islet, celebrated for its giant images, so far south of the equator that coconuts and breadfruit will not grow there, but producing taro, bananas and sugar cane bearing names identical with those of Hawaii and New Zealand.

These plants yielded the most important food staples upon which the Polynesians subsisted. They were common to all the island groups and in addition to them were yams which bore the same vernacular name on Easter Island situated in longitude east of the meridian

[2] The Scientific Monthly, August, 1925, pp. 181–186.

of Salt Lake City and Madagascar across the Pacific and Indian Oceans, on the coast of Africa.

Taro, the staff of life of the Polynesians, from which the Hawaiians make their paste-like poi, is identical with the kulkas which the ancient Egyptians had received from India; seedless bread fruit, propagated from cuttings or sprouts, and which consequently could have been spread only through human agency, had been known for centuries; and the same is true of their sweet bananas, starchy plantains and sugar cane.

Nearly all the islands of the tropical Pacific were fringed with coconuts, identical with the *nux indica* already referred to as encountered by Marco Polo more than two hundred years before Columbus's first voyage. These palms were propagated from the nuts themselves by the islanders, who distinguished several varieties, some of them valuable for oil or food, others for the fiber of their husks, and others, for their shells, which were used as cups for drinking kava or bottles for containing oil or water. Accompanying the coconuts in nearly every group of islands where they grew were enormous coconut crabs (*Birgus latro*) whose claws are specially modified for feeding on the meat of coconuts. These edible crabs were also associated with the coconut in the islands of the Malay Archipelago and the Indian Ocean. They had probably been brought into the Pacific, like the coconut itself, by the islanders, who highly esteem them for food. Another Asiatic plant was turmeric, so extensively used in the East Indies for making curries.

In addition to food plants the islanders cultivated others of economic importance; as, in Samoa and Tahiti, the paper mulberry, identical with that of China and Japan, from whose inner bark was beaten the filmy tissue composing their tapa or barkcloth. The screw pine, or Pandanus, from which they braided their sleeping mats, was identical with a species held sacred by certain castes in India. It is probable that even some of the larger trees had been propagated from seeds carried by the islanders from their ancient home, among them the kukúi, or candlenut, whose oily kernels strung on a spit served for lighting their huts.

The possession by the Polynesians of these important Asiatic plants indicates southern Asia, or more definitely the Malay Archipelago, as the cradle of the Polynesian race. Indeed most of the plants not only bear the same names in the various island groups, but many of these names are distinctly Malayan. In addition to this fact and equally significant in tracing the origin of the Polynesians is the identity of a great many of their primitive words and grammatical forms with those of the proto-Malayans, inhabiting Sumatra, Java and other islands of the Malay Archipelago. The close resemblance of the Malayo-Polynesian languages points to a comparatively recent dispersal from some common center.[3]

I have spoken thus at length of the Asiatic origin of the food plants of the Polynesians and of the introduction from distant lands of many important European fruits and vegetables, so as to offer a contrast to the agriculture of ancient America, which was built up entirely, as I have already shown, from native wild plants and was quite devoid of a single exotic species. Most of these plants had been in cultivation for many centuries, as shown by their wide distribution and the variations they had undergone in adapting themselves to the conditions of

[3] See Safford, W. E., "Cultivated Plants of Polynesia and their Vernacular Names an Index to the Origin and Migration of the Polynesians," in *Proc. of the Pan-Pacific Scientific Conference* (1920). Special Publ. Bishop Museum 7: 183–187, 1921.

climate and soil. Maize, for instance, had become modified into many varieties, some of which in moist tropical situations grew to an enormous height and sent out roots not only from the base of the stalk, but also from several succeeding nodes; others growing in arid desert regions, waist high, sending down a deep tap root in quest of moisture necessary for their existence.

Beans also had become similarly specialized, some of the varieties having adapted themselves to temperate climates, others to desert conditions and others to the moist tropics. Squashes and pumpkins had developed numerous well-marked forms. Before the coming of Europeans these important food plants had spread northward to the Great Lakes and the St. Lawrence River and southward to southern Chile and Argentina. The development of these food plants from wild species and their specialization into distinct varieties in regions widely separated from one another indicates a very long period of cultivation. Equally significant is the discovery of the properties of such plants as tobacco, cacao, coca, from which cocaine is made, the various narcotic Daturas of North America, Mexico and Peru, and the cinchonas, which yield quinine. A knowledge of their virtues points to many centuries of experience and experiments.

Even more striking evidence of the long presence of man on this continent is offered by the various languages spoken by American Indians, which are segregated into distinct linguistic stocks having little or nothing in common and showing no evidence of Old World affinities. Absurd theories have been advanced from time to time; among them that which suggests that the American Indians are descendants of the lost tribes of Israel, another assuming a Phoenician origin and still another insisting on an affinity between certain tribes and the ancient Welsh. It is scarcely necessary to point out that modern Hebrew closely resembles the language of Israel and that modern Greek has much in common with the language of Homer; much more remarkable are the elements in such widely separated languages as Irish, German, Russian, Latin and Greek, which can be traced back thousands of years to the Sanscrit of India. Were any of the American linguistic stocks even so remotely influenced by an Old World language as that of our own is by the Sanscrit, students of philology would not fail to detect their relationship.

What does all this mean? It means that the tribes from whom the American Indians are descended arrived upon this continent at a very remote time, before the languages of the Old World had taken shape; before Sanskrit was Sanskrit, before Hebrew was Hebrew; before the languages now spoken in China and Mongolia had developed; long before the entrance of the Malayans into the Pacific Ocean.

The agriculture and languages of the New World are as truly American as the turkey, the opossum and the armadillo; or the goldenrod, passion flowers and spiny cactuses. Indeed, the American Indian may be regarded as truly a part of the fauna of the New World as the buffalo; in his primitive state subsisting on the wild animal and vegetable food of his environment; in his more advanced stages on the cultivated plants developed by his own efforts from their wild forms. Certainly the cultivated food crops of America, like the languages of the aboriginal Indians, indicate a very remote antiquity of man in this hemisphere; and the absence of intrusions of Old World plants and of linguistic elements points to his isolation from the time of his arrival until the coming of Columbus.

METHODS OF SEA AND AIR NAVIGATION

By Captain J. P. AULT
COMMANDER YACHT *Carnegie*

THE art of navigation nowadays is applied to travel in the air as well as to travel over the oceans, where, through improvement and invention, it has been developed to almost an exact science. Much the same problems are confronted and the dangers are very similar for both the airship and for the vessel that sails the seas. Fog and fire, storms and a lee shore offer much the same menace to the pilot in the air as to the deep-water sailor. One tries to keep his ship aloft and to avoid a crash on his lee shore, the ground below, while the other tries to keep his vessel afloat and at a safe distance from the rocky coast line.

The methods of navigation, the means used in determining the ship's position, its latitude north or south of the equator and its longitude east or west of the meridian of Greenwich, are for the most part based on the same elementary principles which have been used since the time of Columbus.

Dead-reckoning, or keeping track of the vessel's direction of travel and of the distance covered from hour to hour, still forms the basis of all navigation. The refinements and improvements have come in perfecting the means for determining the ship's course and speed.

The invention of the magnetic compass about the year 1400 made navigation possible and we still use this same trembling needle to guide our ships through darkness and fog and over the unmarked oceans, even when traveling by airship.

That the compass does not point true north, but always toward the magnetic north pole, was first emphasized during the first voyage of Columbus. When his navigators discovered that the compass was pointing almost 12° to the west of the pole star a near mutiny arose among the sailors, who were already fearful of the outcome of this mad voyage into the unknown, and the discovery of America came near being postponed for many years. Columbus undoubtedly shifted the needle on the compass card, for in the morning the compass again pointed true to the pole star and the doughty admiral explained that the pole star had shifted its position.

Modern navigation charts tell the mariner just how much his compass points east or west of true north, and by allowing for the deviation due to the presence of iron in his ship he can keep a fairly accurate account of his course over the unmarked ocean highways. Improvements in chart-making, in methods of projecting the surface of the earth on maps and the increased accuracy in the position of coast lines and harbors have been great factors in the steady improvement in navigation.

The first radical change in the method of guiding a ship came only a few years ago with the invention of the gyroscopic compass, which indicates true north very exactly, independently of the earth's magnetic field, due to the mechanical effect of the earth's rotation on its axis, upon a rapidly revolving heavy wheel or weight, called a gyroscope. This instrument is particularly useful on ships of war and on large ocean liners, but a magnetic compass is still carried as a check and for use in emergencies.

Owing to the difficulty of mounting a magnetic compass sufficiently far away from the engine and other disturbing influences in an airplane a new instrument called the earth-inductor compass has been developed by the Bureau of Standards for use in aircraft. This device

again makes use of the earth's magnetic field but in a totally different manner from that of the usual horizontal magnetic compass. A coil is rotated in the earth's magnetic field, and the resulting electric current actuates a pointer on the pilot's instrument board. As long as this pointer remains at zero on the scale, the pilot is steering the desired course. This instrument can be mounted out on the wing of the airplane, away from the iron and electric disturbances in the cockpit.

And now we come to the radio compass, the most important contribution to the science of navigation since the invention of the magnetic compass. The captain of a ship, approaching a harbor, can send out a radio signal, and the men at the different radio compass-stations on shore can determine the direction of the incoming signal by slowly rotating the large loop-antennas of their radio-compasses until the signal is loudest. The observers then "radio-wave" back to the captain his bearing or direction from their respective stations. By plotting these bearings on his chart the captain can very quickly and accurately locate his position, and this performance can be repeated as frequently as desirable in spite of fog, clouds or darkness. There are at present about thirty of these stations on the Atlantic coast and more are to be established. Before many years all the harbors as well as all important lighthouses of the world will be equipped with radio-compasses. Accurate bearings may be obtained when the ship is 150 miles offshore, and the method may be used at a distance of one thousand miles if the proper corrections for the curvature of the earth are applied.

Using practically the same principle, a new scheme has been devised for guiding the aircraft pilot between stations. Directional radio signals are sent out between the two stations and as long as the pilot follows the path of these signals a white light is shown on his instrument board. Any deviation in the flight of the airplane to right or left of this path is shown by different colored lights, and the pilot must change his course in the proper way to bring the white light on again. Future improvements and developments in the use of the principle of the radio-compass will go far toward solving the problems of aerial navigation.

For polar work, where the directive force of the earth's magnetic field is very small, owing to nearness of the magnetic pole, the usual magnetic compass is not satisfactory on aircraft and a sun-compass has been devised for use when the sun is shining. This instrument works somewhat on the principle of the sun-dial and the method can be illustrated by taking your watch and pointing the hour hand toward the sun. The approximate north-south direction will be halfway between the hour hand and the 12 o'clock mark on the watch. Since the sun-compass depends upon a knowledge of the airship's position for its indications, any errors in dead-reckoning will introduce errors in the direction as indicated by the sun-compass.

Not only must the course of the ship be known in dead-reckoning the position, but the speed through the water, or through the air, must also be determined in some manner. In olden days they had the chip-log and the hour-glass. The knots in a line were so spaced that their distance apart bore the same ratio to a mile that 28 seconds bears to an hour. The chip would be thrown overboard and the number of knots on the attached line which passed over the rail while the sand was running through the neck of the 28-second sand-glass indicated the ship's speed per hour through the water. And so we have come to call the nautical mile a "knot." In modern times we determine the speed of the vessel by

counting the number of revolutions of the ship's propellor or reading the patent log which indicates the speed directly on a dial connected by a line to a small revolving device trailing along behind the vessel. The air pilot has his ground-speed indicators when the ground is visible, or his smoke bombs or flares if out over the ocean, with which to determine his speed over the ground or over the water.

Owing to uncertain and variable ocean-currents and wind effects, a dead-reckoned position of the ship must be checked up by some other means. Since ships first began to sail the seas, the sun has been used to determine the latitude, a simple computation of the altitude at noon being all that is required. Before the invention of the chronometer-watch about 1761, the longitude was determined very approximately and rather infrequently, I imagine, by long and tedious calculation of measured distances between the moon and various stars and planets, the so-called "lunar distances."

For many years the practice was to sail north or south to the latitude of the place of destination and then sail east or west until land was sighted. Edmund Halley, the famous astronomer, during his voyage on the *Paramour Pink* in 1689–1700 followed this method, and he was as much as three hundred miles out of his reckoning at times. Halley was making the first ocean magnetic-survey, with a view to using the earth's magnetic field as a means for determining the longitude. We owe to him the present-day method of showing on the chart the lines of equal magnetic declination of the compass.

With our high-grade chronometers, corrected daily by means of the radio, a position at sea can be determined very readily and accurately, provided that some celestial object, such as the sun, star or planet, is visible. The exactness of the resulting position will depend upon whether one or more objects can be used. Observations on only one object will tell the navigator that his vessel is located somewhere on a line, the so-called Sumner line. When the navigator measures the altitude of the sun, for example, he may be anywhere on a circle whose center is the point on the earth immediately below the sun and whose radius is equal to the zenith distance of the sun, or 90 degrees minus the measured altitude. A dozen navigators scattered anywhere on this circle, thousands of miles apart, would all get the same altitude of the sun at the same instant of time. For example, if you want to tie a ribbon a mile long to the top of the Washington monument in Washington and then circle around it like a May-pole, stopping every once in a while to measure the altitude of the top, you will find that you will get about 6 degrees wherever you try it. While you are crossing the Potomac River on your circular path, suppose you stop to measure the altitude and to locate your position, then you know that you are somewhere on a very short segment of this circle, and this segment, for all practical purposes, you can consider to be a straight line, at right angles to the direction of the monument. So the navigator who measures the altitude of the sun or star knows only that he is somewhere on a line which is at right angles to the bearing of the object observed and which is not often more than thirty miles long, due to the accuracy of his dead-reckoned position. This line is called the Sumner line, after the American navigator, Captain Thomas H. Sumner, who discovered the method in 1847 and which is the basis of all modern navigation where astronomical methods are used, both at sea and in the air.

It is seen that one line is not sufficient to completely fix the position of the vessel, so another line is necessary, either

from observations on another star or planet or the navigator can observe the sun again after an interval of a few hours, if conditions are right, and the intersection of any two lines completely fixes the position. Venus is often used with the sun for this purpose during the daytime and occasionally even Jupiter.

The new acoustic sounding device is being found increasingly useful in advising the navigator of his approach to land and to assist in determining the position at sea. A sound wave is sent into the water from the bottom of the vessel and a precise measurement of the time it takes for the sound to reach the ocean bottom and to be reflected back again to the ship gives the depth of the water. This depth is shown continuously and automatically on a dial on the navigator's bridge, and this gives immediate warning of approach to shore.

Many improvements have been made in instruments, charts and methods of navigation, notably by Maury, Marc Saint Hilaire, Aquino, Littlehales and others, so that at present a determination of a ship's position involves very little calculation.

Just as the use of astronomical methods came to the aid of dead-reckoning, so radio is now completely revolutionizing the older methods in the science of navigation and the radio future will witness vessels of the sea and ships of the air sailing along confident of their position in spite of uncertain winds and of unknown ocean currents, in spite of fogs and of sunless days or starless nights.

MECHANICAL REFRIGERATION

By Dr. W. E. TISDALE
NATIONAL RESEARCH COUNCIL

SUMMER follows winter with such regularity that it might seem, especially to dealers in ice, that there would never be any question as to a market for their product, and indeed it is probable there will never come a time when we shall cease to need refrigeration processes for the preservation of foodstuff, but the handwriting on the wall seems to indicate that the use of ice in homes as a means of refrigeration will soon become obsolete. The office of a refrigerator or cooling chamber is to prevent the growth of microbes which are perhaps best known to you in three different groups—the molds, such as grow on bread and on fruit—especially when the skin is broken; the yeasts, whose principal action is to cause fermentation; and bacteria, which, through their activity, produce disintegration of foodstuffs and cause such familiar poisonings as the ptomains.

Refrigerating temperatures, as ordinarily used in the preservation of foods, do not kill these objectionable organisms but rather keep them in a quiescent state and prevent their growth. These organisms which tend to destroy food will not multiply to any extent at temperatures under 45 degrees Fahrenheit, and a proper refrigerating temperature should therefore be between this temperature and a few degrees below the freezing point of water.

It is possible to install refrigerating machinery in many of the old style ice refrigerators, but manufacturers of this equipment are reluctant to do so for the reason that most ice refrigerators have

a very low efficiency due to improper insulation. Every known substance conducts heat to a certain extent, but so-called dead air perhaps conducts it less than any other common material. A porous substance, such as cork or a very spongy rubber, is filled with minute air bubbles and serves excellently as insulation between the inner and outer walls of a refrigerator. Unless refrigerators are properly insulated, there is a large waste due to the flow of heat from the outside to the inside. If, then, a dealer in high-grade refrigerating machinery refuses to install his equipment in your old ice box, you can be assured that the prime reason is the rendering of real service to you.

In differentiating between the different types of refrigerating machines, it will be necessary to observe the general physical processes which they employ. As a beginning, we are reminded that matter, as we know it, exists in three states—as a solid, as a liquid, or as a gas. In all three states the molecules are in motion and the vigorousness of their motion depends upon the amount of heat they contain, or, in other words, is a function of their temperature. In solids, the molecules are so closely packed that they are much restricted in their vibrations and their interactions are so strong that they remain relatively fixed. In liquids, the molecules are further apart but are still close enough together to have interactions, as evidenced by the slowness with which thick oils flow. Liquids have a surface and take the shape of the containing vessel. In gases, the molecules are so far apart that they have no adherence to each other; their vibration paths are relatively long; they wander all through the space in which they are contained; and because of their collisions with each other and with the walls of the containing vessel, they exert a pressure on these walls.

We can therefore picture what happens in a solid when heat is applied to it. The molecules get further and further apart—as evidenced by their expansion, until finally they are so far apart that they no longer remain in a given form, but need a wall to restrain them from flowing, and thus become liquids. When a liquid is heated the molecules are pushed further and further apart—as again evidenced by expansion—and many of them at the surface get so far away that they do not return, because of interaction. When these molecules leave the surface of a liquid the process is called evaporation. Certain conditions of evaporation are defined as boiling, and the temperature at which a liquid boils depends upon the pressure of the vapor above it—a low pressure of vapor permitting boiling at a lower temperature than will be permitted by a higher pressure of vapor.

Water is very familiar to you in these three states—solid, liquid and gas—and you know it as ice, water and steam. Let us consider a block of ice at a temperature below its freezing point. If heat is applied, it will expand and its temperature will rise until it reaches, on the Fahrenheit scale, 32 degrees. Continuing the supply of heat the ice will gradually melt, but the mixture of ice and water will remain at this same temperature, 32 degrees Fahrenheit, until all the ice is melted. The heat which is necessary to change ice to water, therefore, does not appear as a temperature effect. It is quite evidently a latent heat and is known to those who are concerned with such studies as the latent heat of fusion. After the ice has all melted, further heating of the water will cause it to expand, and its temperature will gradually increase until it begins to boil. As long as the water and the steam are in contact and the pressure is not increased above that equivalent to one at-

mosphere, the temperature of the water will not increase above 212 degrees Fahrenheit. Here again there is a quantity of heat necessary to change the state of a substance—from a liquid into a vapor—and it is known as the latent heat of vaporization. Obviously, if it requires heat to melt the solid and to vaporize the liquid, it can readily be conceived that if a vapor is liquefied or if a liquid is frozen heat will be liberated. Because liquids and gases are easily transferred through pipes, refrigerating machines use them rather than solids as refrigerants, but they all make use of this latent heat involved in the change of state, although they do not necessarily use water as the refrigerant for the reason that it boils at too high a temperature. It is generally much more conveninent to use some substance which boils at or below refrigerating temperatures. Obviously, a liquid which does boil at as low a temperature as 45 degrees will not be found in any quantities in nature because it would have boiled away under ordinary outdoor temperatures. Such refrigerants, therefore, are usually manufactured, and ammonia, carbon dioxide, sulphur dioxide, ethyl chloride and methyl chloride are the most common ones. They are expensive, and systems employing them do not permit the vapor to escape in the air, but by their process condense it and revaporize it over and over again.

You will, of course, understand that there is physically no such thing as cold. A space is cold because of the absence of heat and our refrigerating devices are therefore devices to remove heat from a given space. In applying physical principles to the process of refrigeration, several distinct methods are employed, but in general, they all utilize electrical devices for power and regulation.

Compression System

The compression system of producing refrigeration temperatures utilizes a substance such as ammonia (which boils at 33° below zero) and provides a chamber or coil in which rapid evaporation or boiling takes place, together with a pump which will compress the vapor sufficiently to liquefy it. Heat must be supplied to the refrigerant in order to cause it to evaporate or boil, and this is supplied by the air in the refrigerator which, even at zero, contains sufficient heat for this purpose. The abstraction of the heat supplied to the refrigerant causes the air in the refrigerator to cool and this heat, becoming latent in the refrigerant vapor, is carried to the compression chamber. As the pump compresses the vapor to the point of liquefaction, this latent heat again becomes apparent heat in the newly compressed liquid. This newly compressed liquid is cooled by means of circulating water or air surrounding the compression chamber before it is caused to return to the refrigeration chamber, where the cycle begins anew. With the aid of thermostatic control of proper devices, the operation is made automatic.

Absorption System

Refrigerating devices employing the absorption system depend for their operation upon the fact that certain material will absorb or dissolve a large volume of gas. Water at 56 degrees Fahrenheit will absorb or dissolve eleven hundred times its volume of ammonia gas. The rapid absorption of the vapor of the refrigerant causes rapid evaporation—the heat being supplied by the air of the refrigerator. The material which has dissolved the refrigerant vapor must be heated to drive off the vapor, and the vapor must be compressed to a liquid

and cooled as in the compression system of refrigeration.

There has recently appeared on the market a new chemical product in solid form, which has the property of absorbing a considerable volume of water vapor. By its use in a refrigerating device water, under reduced pressure, can be used as the refrigerant, thus avoiding the necessity for a compression pump, because the vapor, when driven off from this substance, can be liquefied by simple cooling. All the devices, however, using the adsorption or absorption system in refrigeration are subject to the criticism that a considerable quantity of heat must be used in driving the vapor from the material which absorbed it and a subsequent cooling of this material.

Air Systems

When a gas or vapor has been compressed and is permitted to expand against a resistance, it does a certain amount of work, and in the process loses heat and therefore becomes cooler. Taking advantage of this physical phenomena, machines are built which compress air up to several thousand pounds pressure per square inch and permit it to expand against a moving piston. In this expansion process the air is cooled and if, after compression and before expansion, the gas is cooled by surrounding it with a water jacket, it is possible to produce a temperature so low that a certain small part of the air will liquefy upon expansion. This is the process used in producing liquid air and liquids from other low boiling-point substances. The process is complicated because it requires a very high pressure pump together with another motor or pump to permit the expansion of the gas against pressure. This system is not employed to any extent for small scale production of refrigerating temperatures.

Vacuum System

Vacuum machines permit the use of ordinary liquids, such as water, which are made to boil by reducing the vapor pressure over them. These refrigerants, being liquid at ordinary temperatures and pressures, are easy to obtain and transport, and have none or very few of the disadvantages of gas refrigerants. They are easy to condense, requiring but little pressure to liquefy their vapors. A very low vacuum must be maintained, however, and for this reason there is much trouble from air leaks into the system. There is considerable promise from this type of refrigerating device, because with proper machine design and a selected refrigerant only moderate volumes of vapor need to be pumped, and the machine may be small.

Vapair System

The Vapair process combines some of the advantages of the vacuum and air systems into one system. A vacuum pump reduces the vapor pressure over a liquid refrigerant and at the same time compresses the residual air in the system and allows it to expand through the liquid. The air in expanding or being violently blown through the liquid does work on it in greatly extending its surface, which markedly increases the amount of evaporation above that possible by vacuum alone. The action of the vacuum pump in rapidly removing this mixture of vapor and air suggests the name Vapair, by which the process is known. This type of device eliminates the expansion motor required in the air machines and eliminates some of the trouble from leaks experienced in vacuum machines where higher vacua are required. The Vapair system involves several fundamentally new principles of thermodynamics.

A NEW PRINCIPLE IN RADIO REPRODUCTION

By Dr. LEE DE FOREST

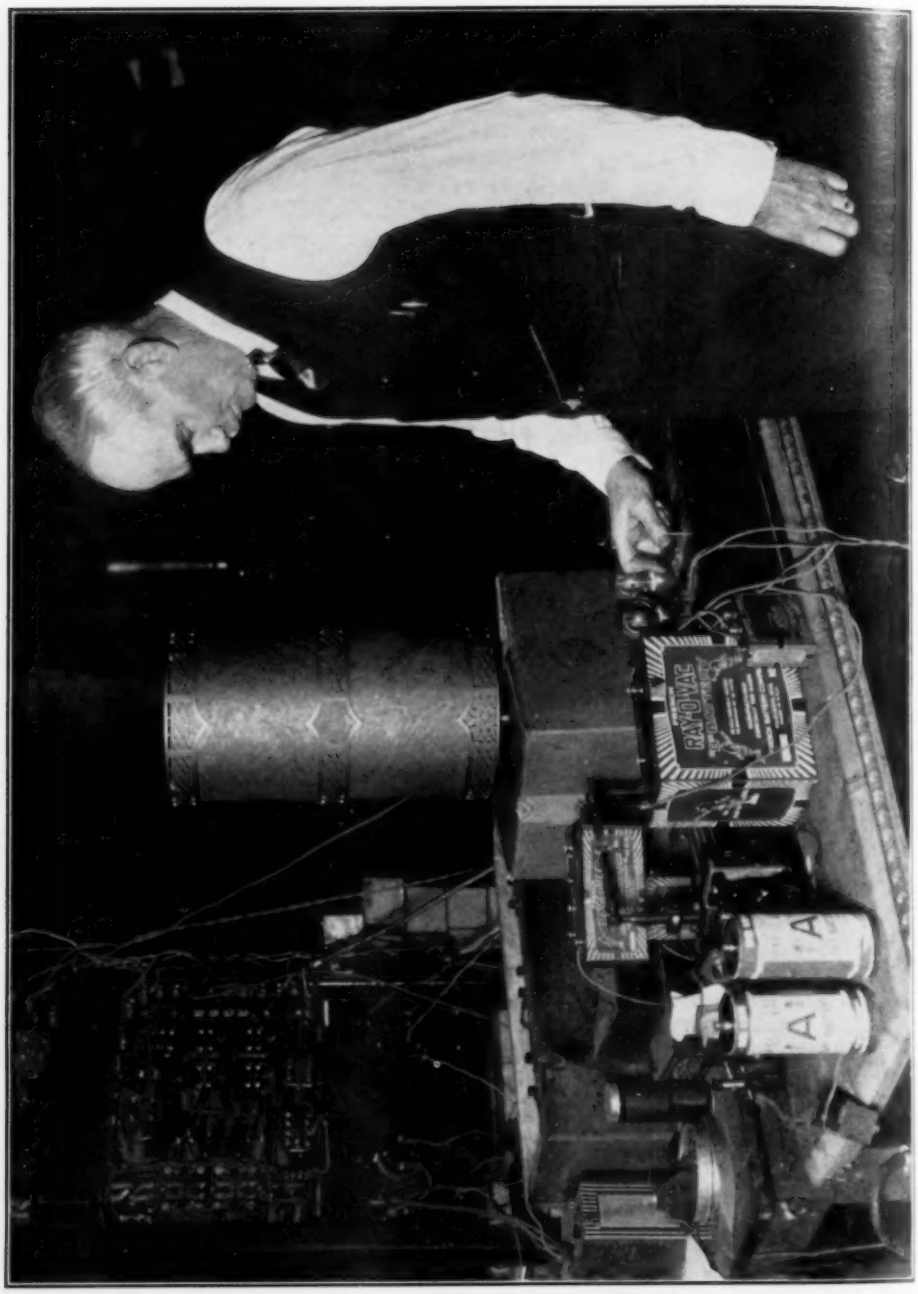
NEW YORK

SINCE the days of the first telephone receiver of Bell, every practical telephone reproducer has been operated on the same general principle, that is, by moving a diaphragm or some form of membrane in the direction perpendicular to its surface. It seems that telephone engineers have been unable to get away from the idea that a medium which produces sound waves must work like a piston. While this method has proven quite satisfactory so long as applied to ear-phones, it has certain inherent defects which become apparent when a larger body of air is agitated, as in the case of a loud speaker.

When used in connection with the Phonofilm, or talking moving picture, these defects of the diaphragm piston-action are quite objectionable. The successful presentation of the Phonofilm requires that a large theater be filled with sound of uniform volume without objectionable intensity in any location. The reproduction, of course, must be perfectly natural so that the audience will not have to exert conscious effort in order to understand what is being said. Furthermore, the reproducer must be free from directional qualities so that the audience will concentrate attention upon the screen and thus gain the illusion that words are coming from the lips of the actors rather than from some adjacent source.

Loud speakers of the diaphragm and horn type are unsuited for use in theaters and large auditoriums, owing in part to the fact that such speakers project their primary sound energy into a space of approximately the form of a cone, with waves of maximum amplitude along the axis, while the diaphragm itself forms the truncated apex. Attempts to produce sufficient volume outside of this conical limit, as is necessary to supply the side rows of a theater, result in objectionable intensity nearer the apex, or in the middle front seats. The line of maximum amplitude along the axis produces a distinct directional effect, making the source of sound easily detected by aural triangulation. Furthermore, the piston impact creates impure waves or distortion, which impair the naturalness of reproduction. Even a large number of speakers placed across the stage produce the same results, each individual in the audience tracing the source of sound to the particular speaker which transmits to him the predominant energy.

In seeking a solution for this baffling problem, I felt compelled to abandon diaphragm reproducers of both the cone and horn types, and as a result discovered an entirely new principle of sound reproduction which avoided all the defects mentioned above. In this new method I found that when an electromagnetic telephone unit is applied tangentially to the edge of a properly curved membrane, instead of at right angles to it, the entire surface takes up the vibrations in a gentle whipping or rolling action and sends out sound waves of the correct amplitude in all directions. Many of these waves are projected radially by the displacement of the membrane normal to its surface, but the



DR. LEE DE FOREST

THE AUDALION

predominant action seems to be due to either the rolling or the frictional effect which transmits waves tangentially. This is shown by the fact that the maximum sound energy is propagated from the area of the membrane which has the least radial displacement and the greatest circumferential motion, as the portion near the edge to which the tangential impulses are applied.

It was found that the maximum efficiency is obtained when the membrane is approximately cylindrical or a section of a cylinder; but a true circular contour is not satisfactory because it imposes a variety of stresses which results in distortion due to creating natural periods of dissonant vibrations. The membrane must be permitted to assume a particular horseshoe form, or more specifically, a catenary, and there must be an opening in the back so as to avoid resonance, or the "barrel tone."

The distinctive characteristics of this new form of wave action are extreme clarity and naturalness of reproduction, and the ability to fill a large room with uniform volume without objectionable intensity nearby or in any one direction. This may be explained by the fact that a larger section of air receives the primary impulses at a uniform amplitude and in all directions simultaneously, thus avoiding certain interferences and the necessity of readjusting the wave action after it has been propagated. In other words, each impulse travels in a straight line from the membrane to the hearer without dissipating its energy in adjacent sound voids as represented by the space in the rear of a horn type speaker. The increased carrying power without intensity is due to the larger source of energy with less concentration per unit of cross-section.

At first I constructed two models of the Audalion, as this new reproducer is called, a large one for theater work and a smaller size for radio use in the home. But I found that the smaller size was

equally efficient in the theater, owing to its wonderful carrying power and distributive qualities. The actuating unit, which is of the balanced armature type, is extremely sensitive both to the lowest musical note and to the highest audible overtones. This sensitiveness is essential to the faithful reproduction of the individual instruments of an orchestra in their natural timbre, but it also necessitates good broadcast reception, for a reproducer can not make up for the deficiencies of the receiver. Radio is rapidly approaching a high degree of efficiency, however, and both receiver and reproducer must contribute their share. Furthermore, the public is demanding better equipment, and as the mystery of radio wears off, people are learning the importance of careful tuning and the proper care of batteries.

An interesting psychological reaction has been observed in the introduction of the Audalion. Probably the most beautiful masterpiece of Beethoven would receive scant appreciation from primitive peoples whose weird chants have profound emotional and even religious significance to them. Likewise, modern jazz, which has such strange effects upon our younger generation, receives little commendation from the older folks whose tastes run more to the dreamy waltz. The confirmed radio enthusiast has become accustomed to the "horn-tone" of reproduction, which he is prone to call "fullness" and "blending." When he hears clear and natural reproduction, therefore, something seems to be lacking. On the other hand, the trained musician who has had pronounced aversion to radio reproduction, or "canned" music of any kind, readily appreciates this new style of reproduction for the very reason that it avoids the added resonance to which he has objected. These comparisons merely show that so far as music is concerned, at least, we prefer that to which we are accustomed. But since the public is becoming more discriminating every day, it seems safe to predict that in the long run the best quality of reproduction will prevail.

ELECTRICAL PHONOGRAPH RECORDING

By JOSEPH P. MAXFIELD

BELL TELEPHONE LABORATORIES, INC.

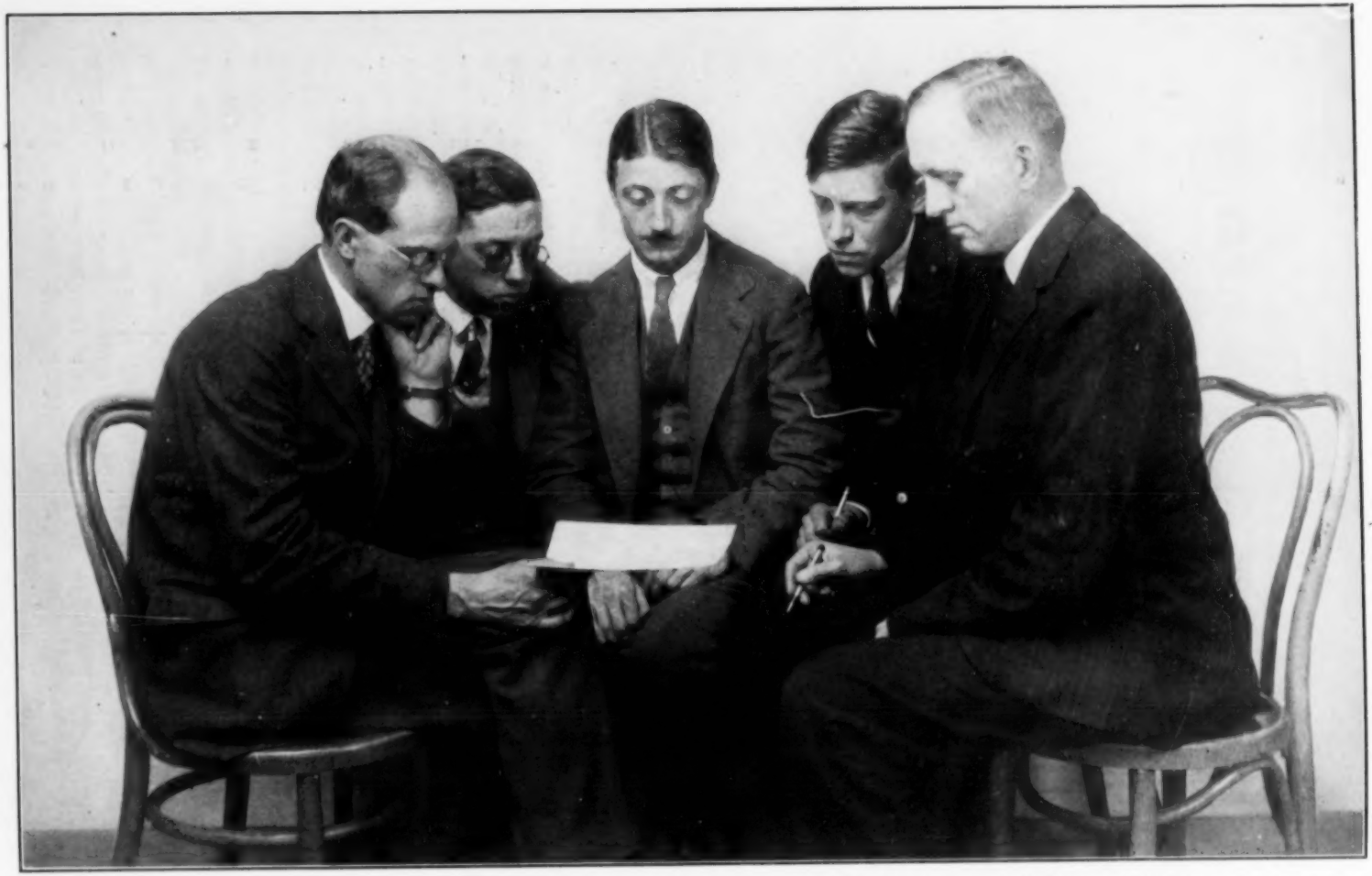
THE history of the development of nearly all the technical arts has shown that from time to time the progress of the art has received an impetus through the adoption of some new principle. In the periods between these advances take place the improvements in details which result in the new principle being applied to the best commercial advantage.

This has been so in the talking machine art. Early in its development, the introduction of a duplicating process by means of which large numbers of records on long-wearing material could be made from a first impression on soft wax allowed the talking machine field to be exploited commercially. Then the development of a smooth-running motor-driven machine in place of the early hand-operated ones opened up a field of higher class music.

The method of recording with which this paper deals represents the outcome of the application of new principles to the phonograph art. These new principles have been largely borrowed from the results of research on telephone circuits. As is well known, analogies between mechanical and electrical circuits have been used in the teaching of electricity for some years. However, in the field of application, particularly in the communication art, problems of wave transmission in electric circuits have been very completely worked out. When a survey of the talking machine problem was made, it was early realized that most of the problems were of a wave transmission character and the work was greatly aided by reversing the use of the analogies between the mechanical and the electrical circuits to give an explanation of the behavior of mechanical systems in terms of known electrical systems.

Before considering the methods involved, it may be well to make a rough division of the problem into its component parts. The storing or recording of sound requires first a mechanical system which will respond faithfully to the sound waves which are to be recorded. Then there is required some material in or on which this sound may be recorded and an intervening system which permits the sound waves to make the record in this material. In the usual case, and in that with which we are particularly concerned here, there is a mechanical system which will vibrate in response to the sound which is to be recorded and directly through some mechanical linkage or less directly through electrical equipment drive a cutting stylus which will impress a wax record.

The first consideration, therefore, is the character of the sound which is to be recorded, including all the effects of reverberation and the general questions of studio design. Next to be considered is the manner in which the cutting instrument shall impress this speech or musical record upon the constantly rotating wax disc, which disc is commonly called the wax master. In this connection, there will be discussed also the relative value of the electrical and mechanical linking of the cutting knife with



SOME OF THE PRINCIPAL WORKERS ON THE PROBLEM OF ELECTRICAL PHONOGRAPH RECORDING. TO THE LEFT, J. P. MAXFIELD, IN CHARGE OF THE WORK; IN THE CENTER, S. S. A. WATKINS, RESPONSIBLE FOR ADAPTING THE EQUIPMENT TO COMMERCIAL USES; ON THE RIGHT, H. C. HARRISON, CONTRIBUTOR OF MOST OF THE FUNDAMENTAL IDEAS CONCERNED IN THE DEVELOPMENT OF THE RECORDER; NEXT TO MR. HARRISON IS A. T. TAYLOR, EXPERT IN THE ASSEMBLY, ADJUSTMENT AND CARE OF THE RECORDERS, AND NEXT TO MR. WATKINS, A. C. MILLARD, EXPERT IN CARE AND CONTROL OF THE AMPLIFIER EQUIPMENT.

the mechanism which receives the sound waves.

In recording work, therefore, one of the important factors deals with the acoustics of the room in which the recording is done. It is probable that the most comprehensive single factor in this connection is the time of reverberation, *i.e.*, the time taken for a sound of given intensity to die away after the source has been stopped. Experiment has shown, however, that the shape of the room and the position in which the curtains and other absorbing materials are hung play a part in the excellence of the music. By a proper control of the acoustic properties of the recording room, it has been possible to record the so-called "atmosphere" surrounding the music. When this result has been accomplished, the listener seems to "feel" the presence of the artists to whose record he is listening.

If a studio is too highly damped or, as a musician would say, "too dead," all the instruments lack the vibrant, ringing tone to which we are all accustomed and which lends life and spirit to the music. The impression on the listener is very similar to that produced by music played in the open air where no floor or sounding boards are provided to reflect the sound. If a room is insufficiently damped, or in the musician's terminology "too live," two effects are produced, both of which are disagreeable. The first is a tendency of one set of notes to blur with those produced immediately before and after, and in the case of large orchestras the blurring is so bad as to make it impossible to pick one instrument from another. The second effect is to leave the listener with the impression that he is listening to music being played in a totally bare and empty room. It is interesting in this connection that the studio must be slightly more damped than the rooms in which we are accustomed to listen to music, because the phonographic process is what we call single channel, that is, it "listens" with "one ear" only. The effect of slightly too live a room can be imitated by any one by stopping up one ear and listening with the other one alone. When the acoustic conditions are correct, the illusion produced is so good that the reproduction is raised from the class of minor amusement to that of an artistic production.

In the case of large orchestras and similar types of music, the reverberations in the hall or theater constitute part of the musical and artistic effect. The solution of the problem of recording these effects in such a manner that when the music is reproduced in a living room the effects appear to be those desired has constituted one of the real advances in the recording art.

The second important factor is the range of notes or frequencies which it is possible to record and reproduce. The range of notes or frequencies which occur in speech and music, particularly where all types of music, including such instruments as the pipe organ, are concerned is from about sixteen cycles per second to approximately ten thousand. It has been found, however, that very acceptable reproduction of most types of music, and of speech, can be obtained by faithfully reproducing the band of notes starting about two octaves below middle C and including up to approximately one half octave above the top note of the piano.

In this connection, it should be made clear that a reproducing system which fails to reproduce all frequencies below, let us say, middle C will, nevertheless, reproduce the auditory sensation of a musical note whose fundamental is below this, even though the fundamental and one or two of its harmonics have been eliminated in the reproduction. While this elimination of the lower components in no way changes the apparent pitch of the note, it does change what is commonly called the "character" or

SOME OF THE PRINCIPAL WORKERS ON THE PROBLEM OF ELECTRICAL PHONOGRAPH RECORDING. TO THE LEFT, J. P. MAXFIELD, IN CHARGE OF THE WORK IN THE CENTER, S. S. A. WATKINS, RESPONSIBLE FOR ADAPTING THE EQUIPMENT TO COMMERCIAL USES; ON THE RIGHT, H. C. HARRISON, CONDUCTOR OF MOST OF THE FUNDAMENTAL IDEAS CONCERNED IN THE DEVELOPMENT OF THE RECORDER; NEXT TO MR. HARRISON IS A. T. TAYLOR, EXPERT IN THE ASSEMBLY, ADJUSTMENT AND CARE OF THE RECORDER, AND NEXT TO MR. WATKINS, A. C. MCLAIN, EXPERT IN CARE AND CONTROL OF THE AMPLIFIER EQUIPMENT.

FIG. 1. PICTURE OF AN ORCHESTRA RECORDING FOR THE ACOUSTIC PROCESS. THIS PICTURE WAS FURNISHED THROUGH THE COURTESY OF THE VICTOR TALKING MACHINE COMPANY, CAMDEN, NEW JERSEY AND THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

"timbre" of the note. The "metallic" quality of tone characteristic of the older type talking machine was largely brought about by the failure to reproduce these lower tones.

In attacking the problem of improved recording methods there are two obvious lines of procedure. The first is to make use of the energy of the sound waves for the purpose of operating the recording instrument. This is the method which has been in use for many years. The second is to make use of high quality electrical apparatus associated with vacuum tube amplifiers in order to give more freedom to the control of the process. This second method has been adopted because the amount of the energy available directly from the sound to be recorded is so small as to make its use extremely difficult, particularly if the artists are to play or sing in a natural manner.

Figures 1 and 2[1] show, respectively, a group of artists recording by the old method and the same group recording by means of the electric process. It will be noticed in Figure 1 that the artists are grouped very closely about the horn. In the case of the weaker instruments, such as the violins, it has been possible to use only two of standard construction. The rest of the violins are of the type known as the "Stroh," which

[1] They will appear in the Proceedings of the institute with a paper to be read at the mid-winter convention.

FIG. 2. PICTURE OF THE SAME ORCHESTRA SHOWN IN FIG. 1, BUT RECORDING FOR THE ELECTRIC PROCESS. THIS PICTURE WAS FURNISHED THROUGH THE COURTESY OF THE VICTOR TALKING MACHINE COMPANY, CAMDEN, NEW JERSEY AND THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

is a device strung in the manner of a violin but so arranged that the bridge vibrates a diaphragm attached to a horn. This horn is directed toward the recording horn, as shown by the player in the foreground. With such an arrangement of musicians, it is very difficult to arouse the spontaneous enthusiasm which is necessary for the production of really artistic music.

In Figure 2 the musicians are sitting at ease more nearly in their usual arrangement and all are using the instruments which they would use were they playing at a concert. Furthermore, the microphone is now sufficiently far away from the orchestra to receive the sound in much the manner that the ears of a listener in the audience would receive it. In other words, it picks up the sound after it has been properly blended with the reflections from the walls of the room. It is in this way that the so-called "atmosphere" or "room-tone" is obtained.

In the old process it sometimes happened that after the instruments had been arranged in such a manner that the relative loudness of the various parts had been balanced correctly, it was found that the whole selection was either too loud or too weak. This usually meant a complete rearrangement of the players. With the flexibility introduced by the use of electrical apparatus including amplifiers (see Figure 3), the control of loudness is obtained by simple manipulation of the amplifier system and is in no way related to the difficulties of the relative loudness of one instrument to another. The only problem for the studio director in this case is to obtain the proper balance among the various musical instruments and artists. The

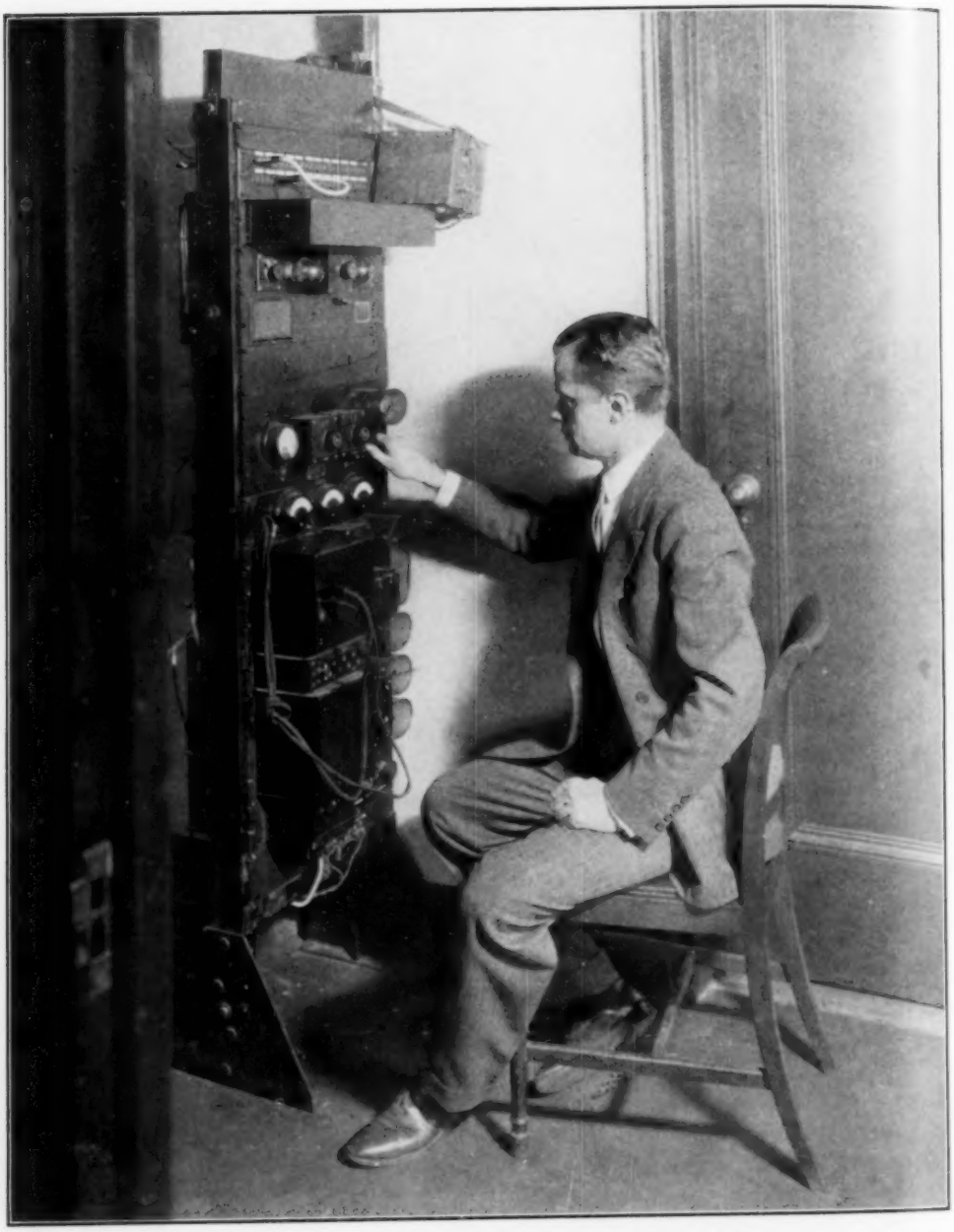


FIG. 3. THIS FIGURE SHOWS AN OPERATOR MANIPULATING THE AMPLIFIER SYSTEM TO OBTAIN THE CORRECT LOUDNESS. THIS PICTURE WAS FURNISHED THROUGH THE COURTESY OF THE COLUMBIA PHONOGRAPH COMPANY, NEW YORK CITY.

FIG. 4. A RECORDER IN PROCESS OF CALIBRATION BY MR. H. A. SUMMERS.

advantages derived from this added ease of control are also made manifest in that it is much easier and less tiresome for the artists and it is usually possible to make more records in a given time.

It may be interesting to follow the course of the sound vibrations, from the time they are produced until they appear as an irregular groove on the phonograph record. The sound is first picked from the air by means of a spe-

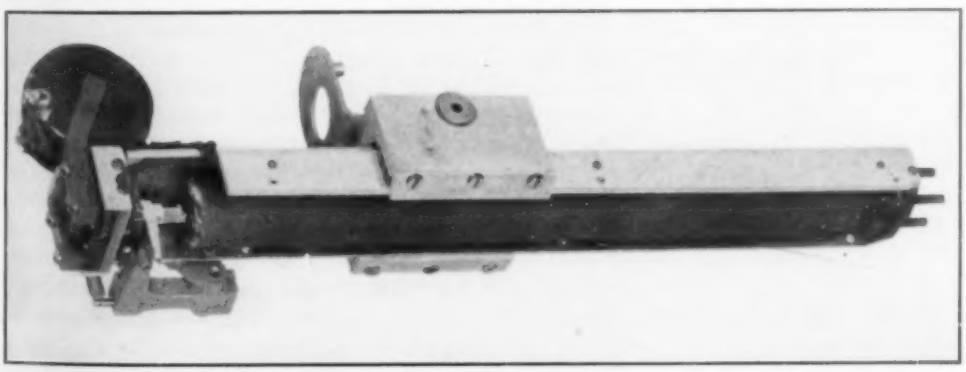


FIG. 5. THIS FIGURE SHOWS AN ELECTROMAGNETIC RECORDER COMPLETE EXCEPT FOR THE BOTTOM OF THE CASE.

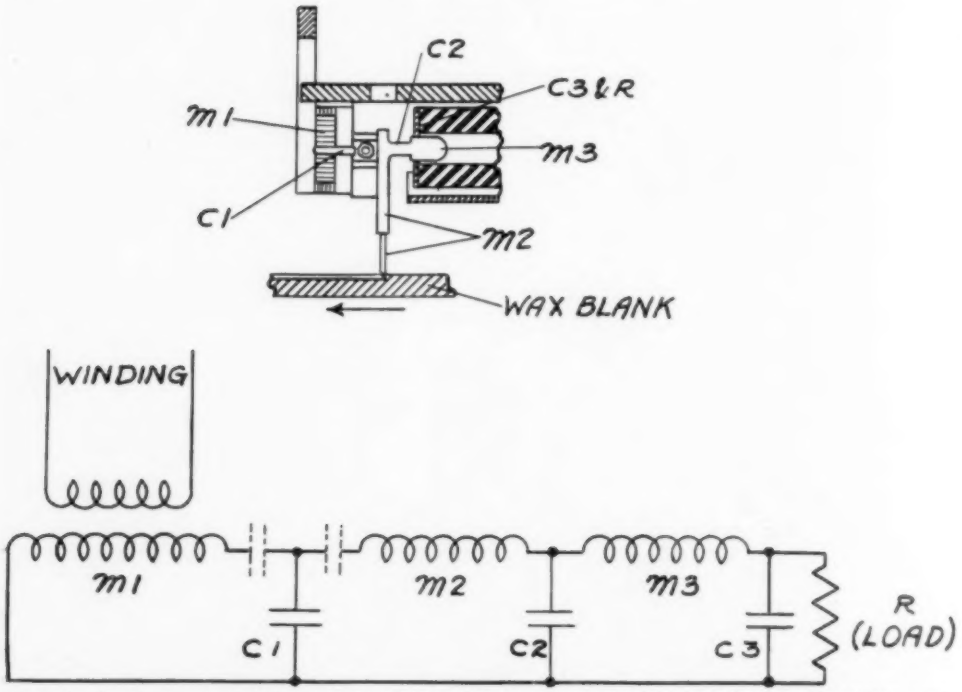


FIG. 6. THIS FIGURE SHOWS, ABOVE, A DIAGRAMMATIC SKETCH OF THE RECORDER MECHANISM AND, BELOW, THE SIMPLIFIED EQUIVALENT ELECTRIC CIRCUIT OF THE SAME INSTRUMENT.

cial telephone transmitter which is essentially an instrument which translates into voltage fluctuations the air pressure fluctuations which strike its diaphragm. These voltage fluctuations, which are exceedingly small, are amplified by distortionless vacuum tube amplifiers until they are of sufficient power to operate the device which cuts the permanent record in the disc of soft wax. This instrument, known as the recorder, is one of the examples of the application of the wave transmission theory of electric circuits to mechanical systems.

A picture of one of these recording instruments is shown in Figure 5, while a simplified diagram of its equivalent electric circuit is shown in Figure 6. In actual practice it has been necessary to take account of some second order factors which have been left out of this diagram as they greatly increase the complexity.

Referring to Figure 6, the inductance labeled m_1 represents the mass of the armature which when acted on by the magnetic field forms the driving portion of the mechanical system. The condenser c_1 represents the flexibility of the shaft connecting the armature to the stylus holder, m_2 represents the mass of the stylus holder and stylus, c_2 the flexibility of the shaft connecting the stylus holder with the metal piece which fits into the rubber damping element, m_3 the mass of this metal piece, and c_3 and r represent the characteristic of the damping element. The two condensers shown dotted and unlabeled represent two of the second order factors which were mentioned above.

Those who are at all familiar with electrical filter design will immediately see that this is a filter of the low pass type, providing the two undesignated condensers are omitted. In this particular case the filter has three sections and a terminating resistance. In designing mechanical analogues of such a system, the problem presented is threefold—

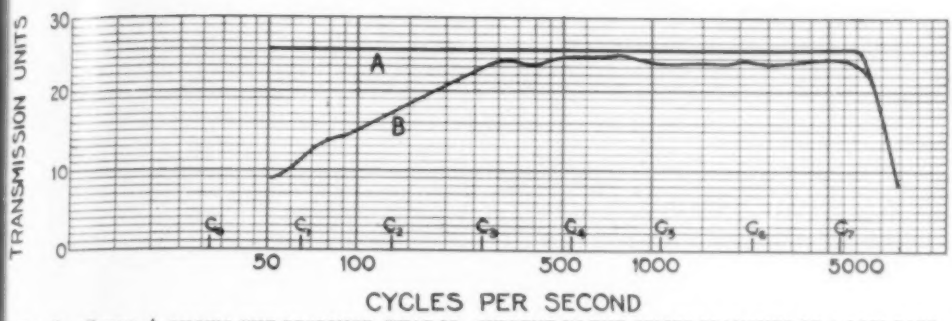


FIG. 7. CURVE A SHOWS THE RESPONSE, THAT IS, CURRENT IN THE SERIES BRANCHES OF A LOW PASS FILTER AS A FUNCTION OF PITCH. CURVE B SHOWS A CALIBRATION OF ONE OF THE RECORDING INSTRUMENTS.

first, that of arranging the parts such that they form repeated filter sections; second, determining the magnitudes of these parts so that the separate sections all have the same characteristics; third, that of providing the proper resistance termination.

The use of the third section and the terminating resistance was decided upon after a considerable amount of experimental work. It was hoped that the resistance of the wax to the back and forth motion of the cutting stylus might be used as the terminating resistance. It was found, however, that under the conditions existing in a commercial recording room, the value of this resistance, even if it were of the correct character, varied so greatly from one wax blank to another as to be unsuitable for the purpose. It is probable also that the value of this resistance is not the same for all notes or pitches lying within the range which it is desirable to record. In the recorder as finally developed, this terminating resistance has been made so large that effect of the wax is negligible in comparison. It acts, therefore, as practically the complete control element of the mechanical filter.

Such a filter when properly designed will have a response *vs.* pitch characteristic of the type shown in Curve A, Figure 7. The actual recorder, however, owing to the presence of the two undesignated condensers of Figure 6, has a loss of response at the low pitch end. This loss is unfortunately necessary in order to avoid the large amplitudes which accompany the low pitched notes and which would cause the trace on the record to cut from one groove over into its neighbor. Curve B of Figure 7 shows an actual calibration of a recorder. While we have no accurate calibration of the older processes of recording, there is considerable evidence to indicate that the fundamentals of notes below middle C were not appreciably recorded and that fundamentals or harmonics lying above the middle of the upper octave on the piano also failed to record. The loss of the fundamentals of the low notes was largely responsible for the metallic tones which accompanied phonographic reproduction, while the loss of the higher harmonics was responsible for the general muffled quality and the inability to hear the sybilants of speech. In other words, the low range is responsible for the naturalness or what is termed the "body" of the music, while the higher harmonics are largely responsible for the detail and clarity of the tone.

When a sufficient range of notes is properly reproduced in conjunction with the proper amount of reverberation effect, it is easy for the listener to imagine himself actually present at the original performance.

It is not sufficient, however, to make improvements of the type described in the records alone. Unless the reproducing machine, that is, the phonograph, is capable of reproducing this full range of notes with little or no distortion, no very marked improvement would be noticed when employing the new type instead of the older type of records. A machine fulfilling these requirements has been developed.

ALFRED NOBEL

THE PROGRESS OF SCIENCE

HEALTH FROM ULTRA-VIOLET RAYS

By Dr. Edwin E. Slosson

Director, Science Service, Washington

Dr. Leonard Hill, director of the National Institute of Medical Research, London, and the leading British authority on heliotherapy, says that to get the full effect of the life-giving rays of the sun, a woman should leave her neck and arms bare, and should wear a short skirt and synthetic silk stockings.

Seems to me I have seen a costume like that somewhere recently, worn by somebody who had never heard of Hill and couldn't tell ultra-violet rays from infra-red. That is the nice thing about science. After a custom has been established, in spite of popular opposition and natural conservatism, the scientists come along and prove the rationality of it. As it is the business of philosophy to provide reasons for what we want to do, so it is the business of science to provide reasons for what we are already doing. Crops were rotated to maintain fertility and baseballs were rotated to prevent the batter hitting them, long before scientists explained why it worked.

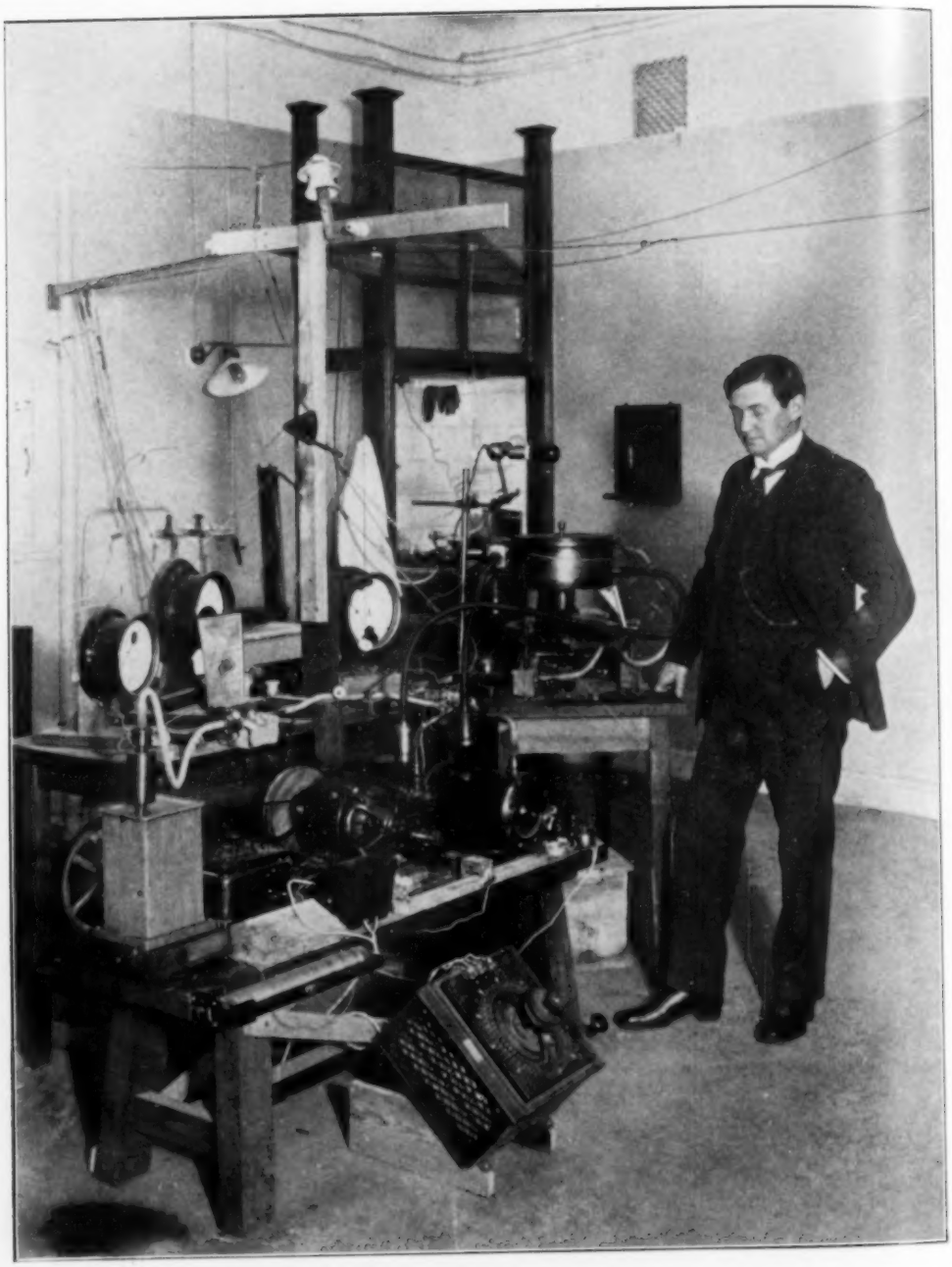
So, too, the summer girl has long been laughed at by the world at large, caricatured by the cartoonists and scolded by the moralists because she followed all too literally the advice expressed in the old song:

> Mother, may I go out to swim?
> Oh, yes, my darling daughter,
> Hang your clothes on a hickory limb
> But don't go near the water.

The portion of the sunshine that has a beneficial effect upon the physiological functions consists of those dark rays which have a wave length of less than one hundred thousandths of an inch. They increase the percentage of lime and phosphorus in the body fluids, and increase resistance to disease. Tanning is an essential part of the process. Now the "bathing beauty" (to use the conventional phrase although she is rarely bathing and even more rarely beautiful) was acting in conformity with all the requirements, so far as local law allowed, when she kept out of the water and spread herself on the sands. Unjustly accused of desiring to make herself conspicuous, she was really seeking the invisible components of the sunlight, and it is not her fault that these are inseparably associated with rays that render her visible to the passer-by and even the by-stander.

Having proved the therapeutic value of ultra-violet rays on the seashore, the summer girl has carried the bathing suit inland and now appears upon the street in all seasons in a costume that meets the requirements of heliotherapist. Though she may be barred from European cathedrals, the American maiden shelters herself under the second amendment to the Constitution, which stipulates that the right of the people to bare arms shall not be infringed. The new style of sleeves in fringes will, if they spread downward, interfere with the exercise of the right as well as the left, but so far the threatened eclipse is being kept at arm's length.

This raises a question demanding masculine consideration. Will not these



KARL MANNE GEORG SIEGBAHN
IN HIS LABORATORY OF PHYSICS AT UPSALA.

sunkist flappers when they grow up—if they ever do—be too big to beat and too smart for the unenlightened wits of men? For, as Professor Hill points out, modern masculine costume could hardly be worse from the standpoint of heliotherapy. Dr. Hill denounces tight collars and long trousers as particularly pernicious to masculine health.

Our Anglo-Saxon ancestors boasted of being "free-necked men," but their degenerate descendants are scrambling for white-collar jobs even though they involve impeding the blood supply to the brain and shutting out the sunshine from their throats.

Golf knickers are being worn oftener and longer (in time). But thick woolen stockings, though they may be more artistic and convenient, are still impenetrable to solar radiation.

The shorter the wave length the less the penetration as a rule. The long red heat rays will pass through the fingers as any one can prove by holding up his hand to the sunlight. The short ultra-violet rays at the other extreme are caught in the outer layer of the skin, yet they are, in some mysterious way yet unexplained, able to affect the entire body. It is largely these rays that cause the tanning, and also the burning and blistering when one takes the sun cure in too large a dose.

Tropical sunshine ranges no farther into the region of these shorter dark chemical rays than the sunshine of our own clime. Since the atmosphere easily absorbs the shorter rays of the sun, the best "bathing beaches" are to be found on arid mountain tops. Where complete clothing is required, either as protection against over-zealous police or excessive insolation, it may be made of a white, thin, loosely woven fabric of cotton, or some of the silk substitutes, such as rayon or lustron. This allows free passage to air and affords the least interference with the passage of the ultra-violet rays.

And if anybody objects to the lessening of clothes on the ground of morality, quote to him the saintly John Wesley: "The less clothing one wears by day and night the stronger he is."

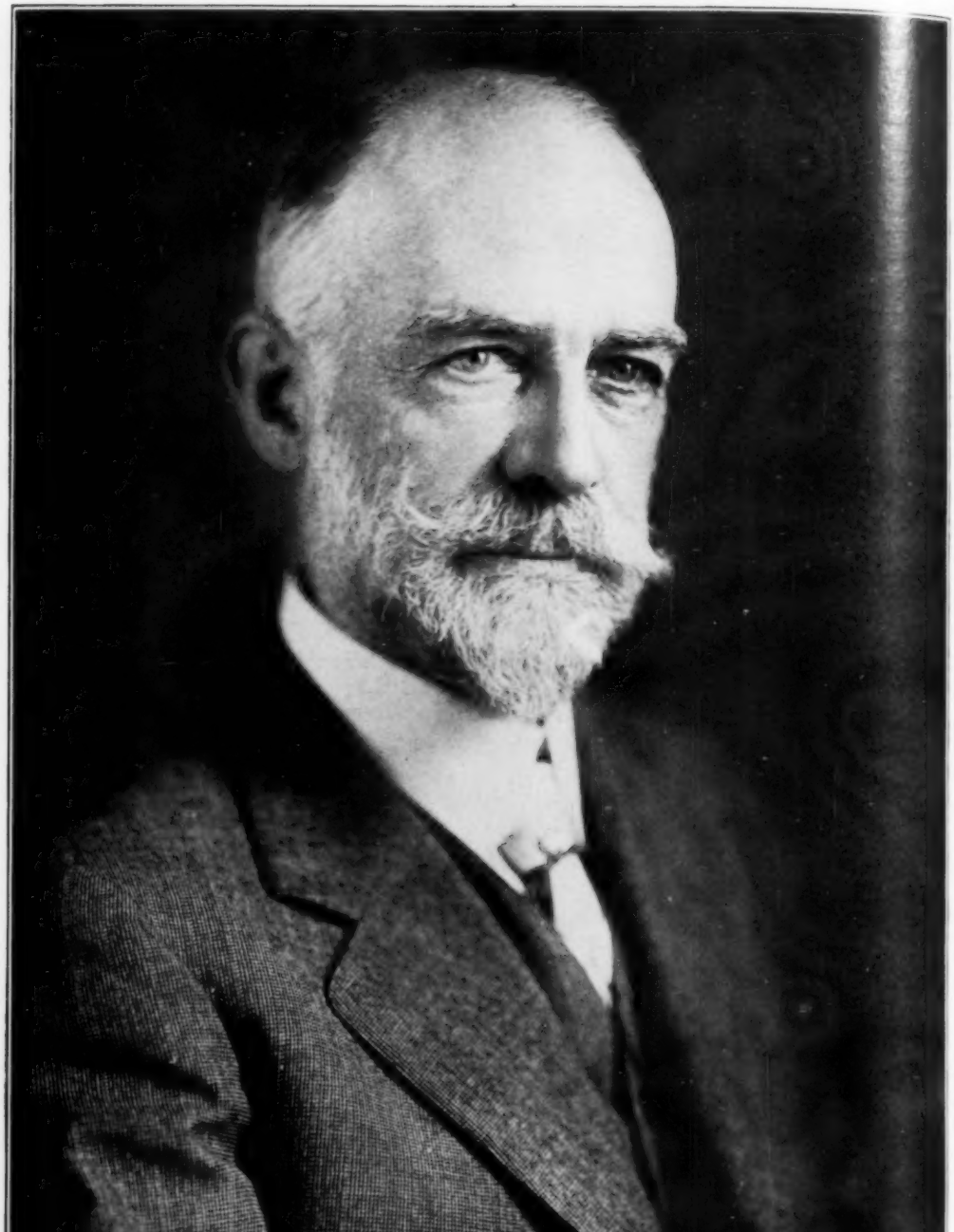
AWARD OF THE NOBEL PRIZE TO PROFESSOR SIEGBAHN

THE Nobel Prize in Physics for 1924 was awarded on November 12 by the Royal Academy of Science of Stockholm to Karl Manne Georg Siegbahn, professor of physics at the University of Upsala, Sweden. This probably is the first occasion on which a man under forty years of age has had a Nobel Prize conferred upon him, although by the terms of the bequest the award was to be made for work done during the preceding year.

Professor Siegbahn has received the prize for his far-reaching work in X-ray spectroscopy. He has carried on with remarkable success the work initiated by Moseley, the young English physicist, whose brilliant career was cut short in the summer of 1915 in the trenches of Gallipoli.

The exact and arduous work of Siegbahn has made possible the measurement to six significant figures of wave lengths in the X-ray region of the spectrum. He has likewise made an exhaustive study of the soft radiations which lie between the ultra-violet and the ordinary X-ray region. His work along these lines is responsible to a large degree for the recent theoretical advances on the distribution and energy properties of the electron. These researches have led to the discovery of three new elements—hafnium and the two eka-manganeses.

The first Nobel Prize in Physics went in 1901 to the great German physicist, Wilhelm Roentgen, who discovered X-rays in 1895. The phenomena of transverse waves—be they the long waves of wireless or the almost infinitesimal



DR. WILLIAM F. DURAND

PROFESSOR OF MECHANICAL ENGINEERING IN STANFORD UNIVERSITY, DISTINGUISHED FOR HIS WORK IN HYDRODYNAMICS, THERMODYNAMICS AND AERODYNAMICS, PRESIDENT OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

"cosmic" waves just discovered by Millikan—continue to claim the attention of our leading physicists.

These Nobel prizes, each originally of the value of about $40,000, were established by the will of Alfred Nobel, who died in 1896. Nobel was born in Stockholm in 1833; he studied in St. Petersburg, and began to assist in his father's engineering works, but soon took up the study of high explosives. In 1864 he took out a patent for dynamite, obtained by incorporating nitro-glycerine with some porous substance. Later he invented ballistite, a nitro-glycerine smokeless powder, but his claim that the patent covered cordite was disallowed by the courts after a lawsuit against the British government. From the manufacture of dynamite and other explosives at his works in Ayrshire and from developing the Baku oil-fields he amassed the great fortune with which he founded the prizes that bear his name.

Three of the awards during the past two years have not been made. The Chemistry Prize of 1924 was assigned to the reserve fund of the Nobel Institute's Chemical Section. Both the physics and chemistry prizes for 1925 have been reserved. The Nobel Institute's statutes provide that if there is no occasion in any one year to award a prize as prescribed by the testator's will, the prize shall be reserved for award in the following year; if, even then, the prize can not be awarded, the prize money must be either added to capital or used to form a special fund for promoting scientific research independently of the yearly prizes. Awards of the peace and medical prizes have been withheld on five occasions, the amount of the prize money in each case being added to capital. Seventeen prizes in all have thus been funded.

THE ENGINEER AND CIVILIZATION

In his presidential address before the American Society of Mechanical Engineers, meeting in New York City from October 30 to November 4, Dr. William F. Durand, of Stanford University, reviewed the beginnings of engineering, the great antiquity of the engineering profession and its contribution to modern civilization. In concluding his address he said:

To sum up the whole matter, the engineer, either as an individual or as a collective type, is simply a link in the chain of human progress—a chain the links of which, in one form or another, run back into a past removed from our own time by tens of thousands of years, to go to no higher figures. With the trend of human progress as it now is, he seems, moreover, to be a very necessary link. He has taken upon himself the peculiar function of developing and translating into use for the needs of civilization the constructive materials of the earth and the inorganic energies of nature, and in connection with the exercise of such function he has acquired peculiar and weighty duties and responsibilities.

There are naturally the duties of self-development and improvement, both individually and collectively as organizations such as our own. This is the duty so well inculcated by the Scriptural parable of the talents. Likewise there are the duties of friendship and of co-operation for the realization of larger ends, and again, both individually and collectively as organizations.

And then it is peculiarly the duty of the engineer to see that, so far as in him may lie, these stores of Nature, of which he is the custodian, are used frugally, with due regard to their limited supply, and having in mind the needs of future

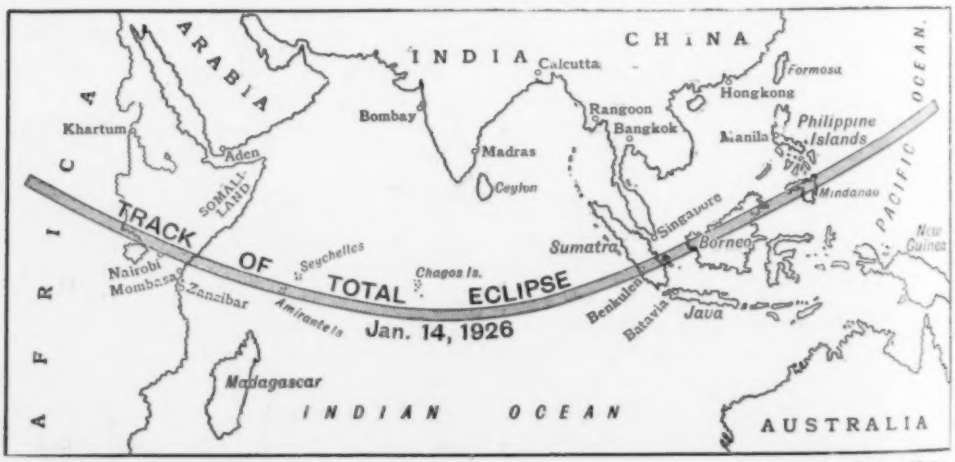
generations. Again, it is his duty to leave behind him some definite increment to that great store of knowledge through which we are able to enter into partnership with Nature, and only by means of which we may hope to more effectively align ourselves with her laws, and thus maintain an ever-ascending gradient of human progress.

Again we must individually as we may, and collectively with definite purpose, endeavor to cooperate helpfully with agencies charged with the training of recruits for our ranks, to the end that there may be a continued and adequate supply to the younger strata in our guild, whence we may hopefully look for leadership and guidance in the future.

And finally, since in the exercise of his functions as an engineer he must of necessity develop and employ habits of mind and methods of study which may be usefully employed in dealing with problems as they arise in all activities in life, therefore should the engineer stand ready to serve, not only in his chosen sphere, but wherever and whenever his habit of mind, his training and his experience may enable him to contribute a helpful element in this great cooperative enterprise which we call civilization.

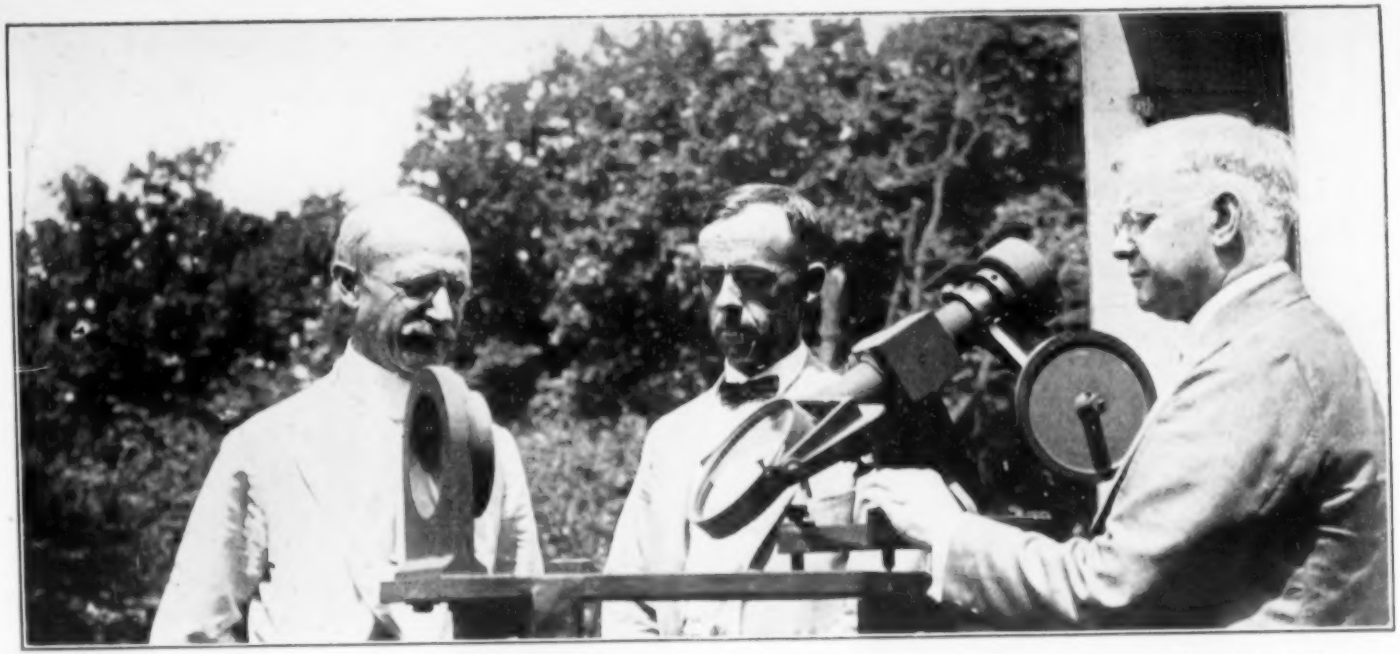
THE TOTAL ECLIPSE OF JANUARY THE FOURTEENTH

MEASUREMENTS of the heat of the solar corona, to be made by astronomers from Harvard University during the total eclipse of the sun visible on the 14th of next January in Sumatra and Borneo, may aid scientists in a solution of the problem of what caused the ice ages that visited the earth at times in the past. The Harvard party, the third group from American institutions to go to Sumatra, is now *en route* on the "President Harrison," which sailed from San Francisco on November 7, and will be chiefly concerned in measuring the radiation from the corona. This announcement was made by Dr. Harlow Shapley, director of the Harvard College Observatory. The expedition is in charge of Dr. Harlan True Stetson, assistant professor of astronomy, whose article on shadow bands observed at the last eclipse appeared in the December issue of the MONTHLY. It will also include Dr. W. W. Coblentz, physicist at the U. S.



From Nature

MAP SHOWING THE TRACK OF THE SOLAR ECLIPSE OF JANUARY 14, 1926



—*Copyright by Harris & Ewing*

ASTRONOMERS OF THE U. S. NAVAL OBSERVATORY

PREPARING TO OBSERVE THE TOTAL ECLIPSE OF THE SUN ON JANUARY 14. FROM LEFT TO RIGHT, CAPTAIN F. B. LITTELL, WHO HEADS THE EXPEDITION, GEORGE L. RAYNSFORD AND G. H. PETERS. THE PARTY HAS LEFT SAN FRANCISCO FOR TEBINGTINGGI.

Bureau of Standards, inventor of the Coblentz radiometer, which was used last year to measure the heat from Mars; Mr. Weld Arnold, explorer from the Amazon expedition under Dr. Hamilton Rice, and Mr. William A. Spurr, Harvard, '25, a student in astronomy.

Similar measurements of the heat of the corona were made by Drs. Stetson and Coblentz from Middletown, Conn., during the eclipse last January. These seemed to indicate that 30 per cent. of the corona radiation is heat, and that the coronal temperature is about 5,000 degrees Fahrenheit. This is considerably cooler than the temperature of the sun itself, so it is thought to be due to the presence of dust-like particles around the sun which reflect some of the sunlight directly, causing the corona which is seen during a total eclipse, but which also absorb some of the energy, and then send it out again as long heat waves. Many such clouds of dark matter are known to exist in various parts of the sky, and it is quite likely, according to Dr. Shapley, that the ice ages in the past, during which the earth was much colder than it is now, were caused by the earth passing through such clouds, which kept out the normal supply of heat from the sun.

To collect the coronal rays, the Sumatra expedition will use apparatus ten times as powerful as that used in Connecticut, while the radiometer will be three times as delicate in measuring the heat. The largest instrument will be a 20-inch reflecting telescope. Other improvements will permit half the time consumed during the precious moments of totality to be saved, and as the eclipse will be nearly twice as long a great many more readings can be made and more accurate results obtained.

Already two expeditions from the United States have gone to Sumatra for the eclipse. These are from the U. S. Naval Observatory at Washington, and the Sproul Observatory of Swarthmore College. The former is in charge of Capt. F. B. Little, astronomer at the Naval Observatory, and also includes Dr. John M. Anderson, of the Mt. Wilson Observatory at Pasadena, Calif. The Sproul Observatory party is under the direction of Professor John A. Miller, director of the observatory, and Dr. Heber D. Curtis, director of the Allegheny Observatory at Pittsburgh, is a member of the expedition. The Swarthmore and Harvard parties will be located at Benkoelen, on the west coast of Sumatra, while the Naval Observatory astronomers plan to locate inland at Tebingtinggi.